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Conflicts of Interests between Different Market Players in Smart Grid Environment

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ABSTRACT OF THE
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The energy business is in a state of change. It is one of the last industries which transforms from analogue to digital. Environmental, political, and technological pressure defy the underlying traditions for a radical change: the energy infrastructure has to be transformed into an active network, with intelligent components and advanced communication gateways. This change will give rise to the development of new business concepts and the coming into existence of new services.

There is no such thing as neutral development, where the competition and roles are cemented the way we see them today. Changing of the business environment forces the stakeholders to fit into the new system. This can cause friction among the actors in the field.

The aim of this thesis is to identify the potential conflicts of interests between the actors in a new environment. In order to find the conflicts, 25 specialist interviews were conducted to map the black spots of the future.

It is found that the pressure focuses mainly to the still unclear line between the regulated and competitive actors and their roles. The role of the regulated network operators' penetration to the service side is seen questionable.Also the ownership of new, emerging concepts such as load control and distributed energy storages are still unsolved and more clear stand from policy-makers and regulations is urged.

Thesis also conducts a study of an aggregator's actions to the grid. It is found that the synchronised control of electric heating with Spot-market signals are done mainly during the night-time, when there is little of other consumption in households. Therefore it can make the situation even better than today from the distribution system operator's point of view.

Keywords: smart grid, conflict of interest, electricity markets, demand response, aggregator, load shifting, Nordic countries

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Energia-ala on keskellä muutosta. Ympäristötavoitteiden saavuttamiseksi on rakennettu uusiutuvaa energiantuotantoa, joka on luonteeltaan epäsäännöllistä niin tuotantomäärältään kuin ajallisesti. Koska sähköverkot ja markkinamekanismit on rakennettu vastaamaan perinteistä systeemiä jossa energia tuotetaan suurissa voimalaitoksissa, aiheuttavat uusiutuvan energian voimakas lisäys uusia vaatimuksia koko infrastruktuurille. Muutos luo tarpeen kehittää uusia ratkaisuja, kuten älyverkot jotka lisäävät automaatiota ja tietotekniikkaa sähköverkkoon.
Markkinaympäristön muutosten myötä myös eri toimijoiden roolit kohtaavat muutoksia. Tämä voi aiheuttaa eturistiriitoja toimijoiden välille: useammalla toimijalla olisi valmiudet ja intressejä murtautua samalle sektorille. Esimerkiksi useammalla toimijalla on tarvetta kuormienohjaukseen.
Diplomityössä on kartoitettu mahdolliset eturistiriidat joita voi syntyä eri toimijoiden välille. Mahdollisten eturistiriitojen kartoittamiseksi tehtiin 25 eri sähköalan osapuolen asiantuntijahaastattelua, jotta työhön saataisiin mahdollisimman kattava kuvaus mahdollisista riskeistä.
Haastatteluiden ja kirjallisuuden perusteella tunnistettiin 33 erilaista eturistiriitaa. Työssä havaitaan että erityisesti reguloidun jakeluverkkoyhtiön roolista on eroavia näkemyksiä ja asiaan odotetaan selvennystä. Älyverkkojen mahdollistamat lisäpalvelut pitäisi saattaa kilpailtuun ympäristöön, eikä näin ollen niitä voisi jakeluverkkoyhtiö tarjota.
Työssä käsitellään jakeluverkkoyhtiön ja sähkönmyyjän välistä mahdollista eturistiriitaa kuormien ohjauksen suhteen. Havaitaan, että Suomessa sähkölämmityksen yhdenmukainen ohjaus aggregaattori-myyjän toimesta tapahtuu lähinnä yöaikaan, jolloin muu sähkönkulutus kotitalouksissa on vähäistä. Näin ollen ohjaus voi jopa parantaa nykyistä tilannetta.

Avainsanat: älyverkot, eturistiriita, sähkömarkkinat, kysynnänjousto, aggregointi, kuormanohjaus, pohjoismaat

Preface

The topic for this thesis was provided by Fortum Distribution Oy, as a part of Smart Grids and Energy Markets (SGEM) project. I want to thank both parties for the possibility of letting me to delve into this intriguing subject.

The examiner for this thesis was Professor Matti Lehtonen from Aalto University and Mr. Oleg Gulich from Fortum Distribution acted as a supervisor. Graditudes to Oleg and Matti for their brilliant guidance. Sincere gratitudes goes also to the interviewees for this thesis, you provided me with insights I otherwise could not have found.

I would like to say heart felt thank you to all the people who have either supported me through my studies or helped me with the writing of this thesis and if you did both you're a sound person and I thank you twice as much! With my hand on my heart I salute you.

Off to new adventures.

It truly has been a pleasure.

Helsinki, 14.12.2012

Olli Aaltomaa

Contents

Symbols and abbreviations

Symbols

σ	Deviation
σ^2	Variance
$\bar{x}$	Mean value

Abbreviations

AMM	Automatic Meter Management
AMR	Automatic Meter Reading
BRP	Balance Responsible Party
CAPEX	Capital Expenditures
CHP	Combined Heat and Power
CVPP	Commercial Virtual Power Plant
DER	Distributed Energy Resources
DG	Distributed Generation
DR	Demand Response
DSO	Distribution System Operator
EC	European Commission
EIA	U.S. Energy Information Administration
EMV	Energiamarkkinavirasto
ENISA	European Network and Information Security Agency
ES	Energy Storage
ESCO	Energy Service Company
HEMS	Home Energy Management System
ICT	Information and Communication Technologies
NordREG	Nordic Energy Regulators
OPEX	Operational expenditures
OTC	Over The Counter
PX	Power Exchange
RAB	Regulated Asset Base
RES	Renewable Energy Sources
R&D	Research and Development
TSO	Transmission System Operator
TVPP	Technical Virtual Power Plant
VPP	Virtual Power Plant

1 Introduction

1.1 Objectives and the scope of the study

The energy business is in the middle of great transition. The world is concerned about the energy production's effects to nature and climate, casting a shadow to conventional energy sources such as oil, coal and natural gas. In order to cut down the emissions from fossil based energy sources there is a need for new kind of energy economy, including renewable energy sources like wind, solar and hydropower.

Transition from traditional energy production to inexhaustible and emission-free production causes challenges to the existing electrical infrastructure. Additional renewable energy sources cause changes to the energy-mix, making it more inflexible due to its intermittent nature: either the wind blows and sun shines, or doesn't. Today's power grids are not equipped to handle sharp increases and large fluctuations in power flows. Integrating this kind of production to the network requires more intelligence from the grid, by adding more self-monitoring, automated components.

As in any major change in business environment, the actors that operate in old environment has to re-evaluate their role and position in a new environment. Searching of the new positions mean that the boundaries from present roles to other actors' area might occur. This can cause frictions between players.

The main objective of this thesis is to identify the potential conflicts of interests that actors experience causing by the change in environment. The focus is mainly on Nordic countries' perspective. Thesis is based on literature study and on interviews. The interviews were conducted in the autumn of 2012, and the interviewees represented the views of different stakeholders in energy domain. The perspectives of interviews include: a generator, a retailer, distribution system operator (DSO), transmission system operator (TSO), a regulator, an aggregator, a representative of large net-buyers of electricity and representatives of Finnish Energy Industries. 22 different persons were interviewed and the list of interviewees can be found in Appendix A.

A Smart Grid rises to the discussion on how to respond to the future challenges the electricity business has to manage. A short introduction to the concept of a Smart Grid, to its benefits and the development phase outlook is found in Chapter 2.

In order to plot out the potential conflicts of interests, the analysis of the roles and responsibilities of the current market players as well as the markets structure where players are situated has to be conducted. Chapter 3 sheds the light on the anomalies of electricity markets in general, giving insight on the characteristics of the Nordic electricity markets' functionality. The market players are introduced with a description of each role.

To find the reasons for the coinciding interests, the understanding about the future development that electricity markets will experience is crucial. As the electricity domain is a complex system, the main factors influencing the prospects has to be identified. In a larger scale, the European level energy strategy as well as national and regulatory barriers have an impact to the road map. In Chapter 4, the future trends of energy market are discussed.

The literature study, backed up with more detailed information from interviews gives the ideas for the problems and possibilities in near-future. Each player has a change in its business. The potential challenges and possibilities for each player are reviewed in Chapter 5.

Conflicting interests are collected in the Chapter 6. In total 33 conflicts of interests were found through the interviews. Each conflict depicts the relationship among the players and illustrates what is the problem. Also the ways to resolve the problem is proposed.

Facilitation of load control is still unclear among players. Main question is who has the right for control, since several stakeholder has the possibility and interest to do demand response. If a retailer would control the loads, it might result in an uncomfortable situation from the distribution network operator's (DSO) point of view. A case study is provided in Chapter 7, where the potential conflict between DSO and a retailer is examined in more detail. The purpose of the case study is to shed a light on what scale the impacts of an aggregator's actions are in a situation where the heating loads are controlled the cheapest possible hours according to the Spot markets.

1.2 Fortum Oyj

Fortum is a Finnish electric utility company, founded in 1998. Fortum focuses on doing business in Nordic and Baltic countries, Poland and Russia. Fortum's main activities are the generation, distribution and sales of electricity and related expert services. [68]

The company has four business divisions: Power, Heat, Russia and Electricity Solutions and Distribution, as illustrated in Figure 1.

Fortum Distribution is the largest distribution company in Nordics, with 156 000 km of regional and local networks, having in total 1.6 million customers in Finland, Sweden and Norway. [1]

Strategy for Fortum aims for continuous development of existing businesses and for market-driven growth in hydro, nuclear and combined heat and power (CHP) production. Furthermore to technical competencies of Fortum, the company's expertise and proven track-record in operating in competitive energy markets has a central role when striving for growth opportunities in existing markets as well as in the rapidly growing and liberalizing markets of Europe and Asia. [68]

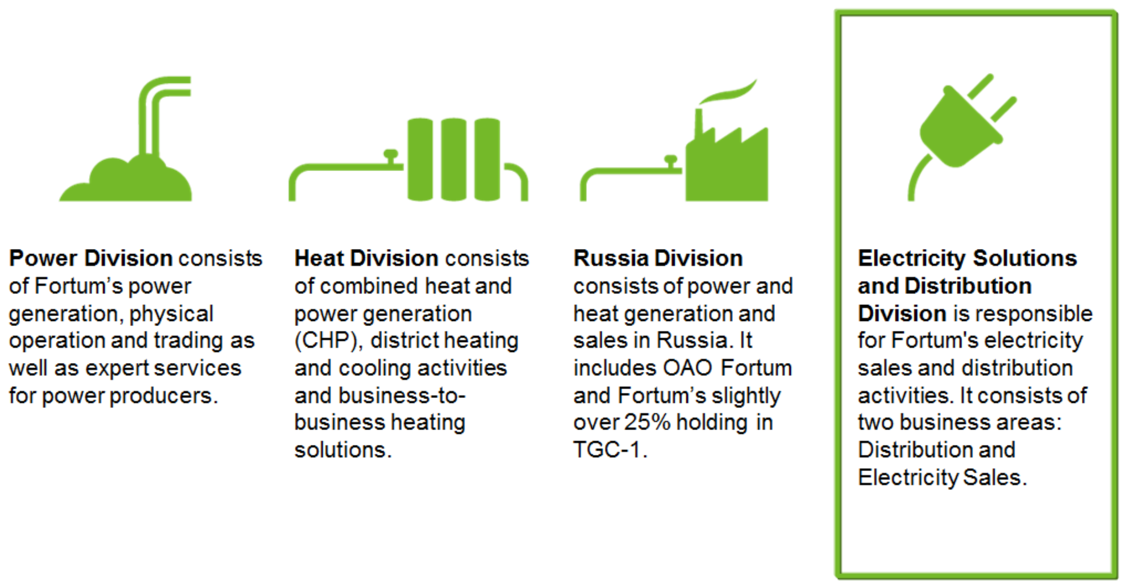

Figure 1: Divisions of Fortum. [1]

2 Smart Grid

The concept of Smart Grid has been the focus point of research in energy world for almost a decade. The idea is to introduce information and communications technology to the electrical grid, and use the information gathered to enable more intelligent grid design and use.

As the Smart Grid enables vast amount of new possible features, it has several definitions ranging from technical perspective to more benefits-oriented approach. EURELECTRIC, the Union of Electricity Industry has defined a Smart Grid as follows:

- EURELECTRIC: "A Smart Grid is an electricity network that can intelligently integrate the behaviour and actions of all users connected to it – generators, consumers and those that do both – in order to efficiently ensure sustainable, economic and secure electricity supply." [8]

A Smart Grid is an enabler on transition to digital world with advanced technologies to monitor and manage the transportation of energy in future, where there are new requirements on how the system works. In higher level it helps the energy system to upgrade its transition to more sustainable world, striving to integrate renewable energy, improve the energy efficiency and cutting the greenhouse emissions. In Figure 2 the transition to more sustainable energy production is illustrated.

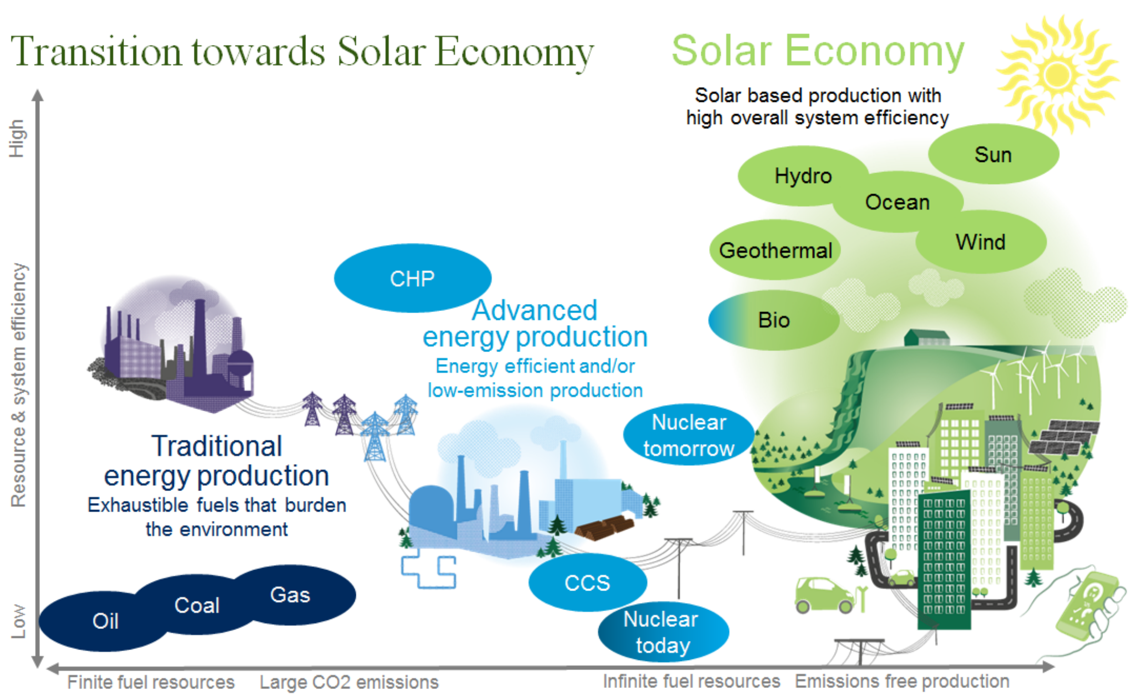

Figure 2: Transition from traditional energy structure to solar economy. [68]

2.1 Drivers

With the changes on how society is using the energy and how it is produced, the existing infrastructure undergoes several radical reforms as well. The main challenge for the infrastructure is the increasing share of renewable energy and the volatility it introduces to the system. In Figure 3 an illustrative example about the intermittent nature of the wind power is shown. With large share of intermittent production in the energy mix, it introduces volatility to the energy system which has not been there before. The energy system has to adapt and find new approaches to keep the system in balance.

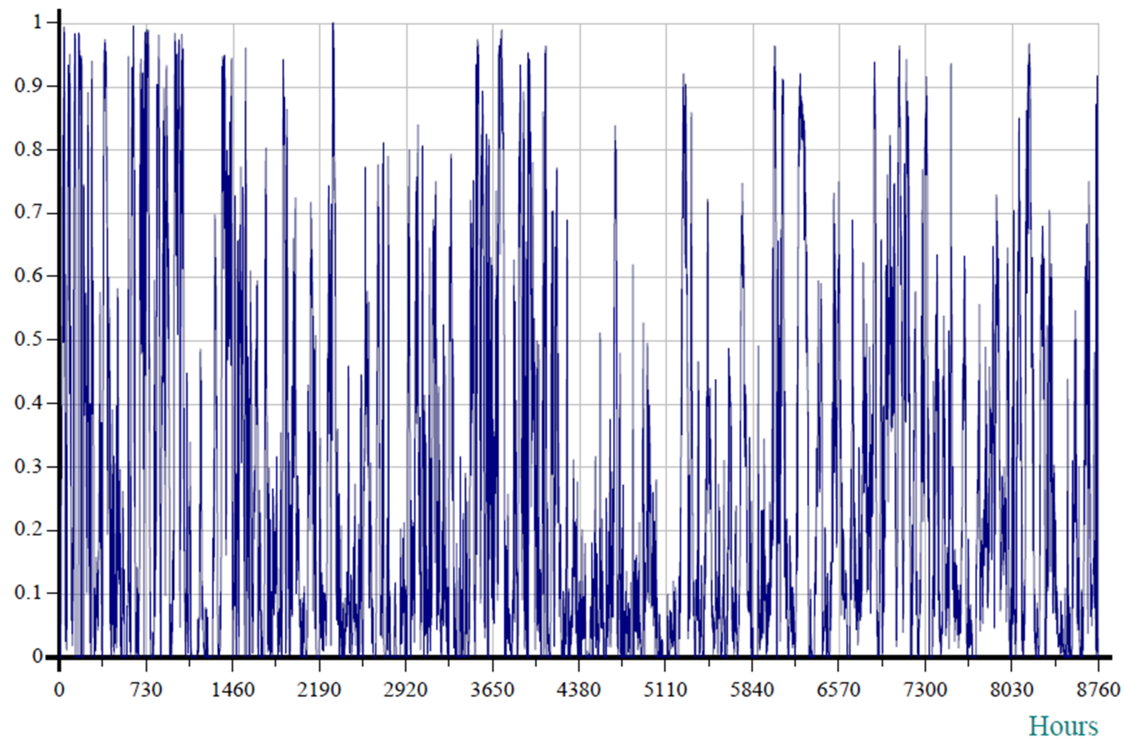

Figure 3: Yearly power production for wind power. [4]

The main focus is to secure economic, reliable and sustainable energy system. The intermittence of renewable energy is not the only challenge connected to it, but also the trend that most of the renewable energy generation will be scattered, which is a main contrast on how we see the energy infrastructure today.

Changes create a pressure to develop and make the infrastructure more agile, proactive, real-time, more intelligent. This is needed to ensure the security of supply, quality of supply and most of all safety in certain level of standard. [55]

2.2 Advantages

Adding more Information and Communication Technologies (ICT) and intelligence to the system is not easy nor cheap. For instance, more expensive hardware has to be added, completely new ICT architectures has to be created and more data is produced, which is needed to verify and store reliably. Nevertheless, if the transition is done carefully, a Smart Grid has the potential to deliver vast amounts of savings. More accurate data is gathered from the state of the grid. Monitoring and finding more efficient solutions to avoid for example grid congestions becomes easier. Processes can be re-designed more optimally, and utilization rate of different components can be improved. With more detailed data from customers desires help to create better products and services which in turn help EU to achieve its targets of energy efficiency, integrate more renewable energy and cut down the emissions.

Another relevant point on why is it necessary to start concentrating on Smart Grid is that the existing infrastructure is getting old. There is a need to vast investments so most optimal and cost-efficient solution is not so straight-forward than before. Technology develops and the old solutions get new competitors from innovative solutions that have lately emerged. [51]

Main difference to the traditional grid design is that it enables the demand flexibility, which means that grid infrastructure can be built in a more optimised way, rather than "fit and forget" procedure that we are seeing now, where the electricity system is unable to take advantage of energy storages and peak load shifting, delivering required amount of electricity and forgetting the possibility to optimisation of components.

In Table 1 a variety of benefits from the Smart Grid to different players are introduced.

A list gives a picture of the various benefits that Smart Grid carries and with certain assumptions the points are applicable. Nevertheless it is very optimistic and best-case-scenario on what the Smart Grid is. As an example, active end users might not be helpful from Network Owner's point of view, if the activity makes the forecasting more volatile which leads to decrease in robustness of supply. Still, even with optimistic bias of the Table, it carries one fundamental lesson: bringing ICT to this sector makes all these listed improvements possible for the first time.

2.3 Challenges

A Smart Grid has great expectations to give solutions to problems energy domain experiences: better efficiency can be achieved, network will become more secure and demand becomes more flexible. It has been the hot topic in energy sector and academic research from circa 2004. Even with a large interest towards it from the energy domain, a lot of work has to be done before it will be developed to the stage where it can be implemented to the infrastructure in a large scale. With new technologies and business cases, barriers and challenges still remain to be solved, major laboratory trials and field tests must be conducted before implementing new concepts in a large scale. Main challenges are presented in Table 2.

More detailed information about the challenges that Smart Grid experiences can be found in [51].

Table 1: A list of benefits for a Smart Grid. [9]

Network Owner	Energy Supplier	End Users
Easier collection of consumption measurements	New products based on new technology	Increased security of supply
Invoicing based on real consumption	Increased customer loyalty	More environment friendly
Load reductions	New customers	Increased possibility to influence energy pricing/costs
Improved customer services (i.e. disruption notices and support, energy displays)	Reduced imbalance penalties	Increased choice of supply
Increased regularity and robustness of supply	Better prognoses and predictions	Predictable energy costs
Improved monitoring of the grid state and quality of supply	Improved balance in operation	Reduced consumption
Active end users	Less exposure towards price variations	Reduced loads
New tariffs for favourable consumption	Reduced maximum effects	Sale of load reduction capabilities
Integration of local production		Sale of local production
Reduction of transport loss		Income on storage
Reduced investments		

2.4 Transition to a Smarter Grid

As the concept of a Smart Grid is holistic by its nature, the approach for the Research and Development (R&D) needs to take on notice by several players in order to achieve optimal solutions. Projects need to adapt a new kind of thinking of R&D, where it is seen more as a network, focusing on collaboration in the whole system level. A Smart Grid has pushed project management to take into consideration more aspects since product and technology complexity increases. The demand to cooperate is essential because of the high technological investments and the need for specialization to even smaller fractions, and finally bringing all this together to create something new and functional. [56]

Not only the complexity is increased because of the collaboration with different electricity market actors, but also because of the synergy to ICT sector. Data is gathered and distributed, which means that solutions from ICT are needed to enable the transition. System becomes more complex than ever before.

In Figure 4, the projection of the Smart Grid development is shown.

Table 2: A list of challenges for a Smart Grid. [51]

Technological Challenges	Communication Coverage of Transmission and Distribution Grids Choice of Communication Technology Information Security Distributed Energy Resources Integration Challenge Distribution Automation Synergy with Advanced Metering Infrastructure Cheap Energy Storage Technology Grid Network Design
Economical Challenges	Market Barriers to the New Business Models Social and Economic Issues
Business Challenges	Integration Challenge Energy Management
Regulation Challenges	Interoperability Lack of Standards and Regulations

The initial R&D stage has been carried out and at the moment the development phase has been focusing on pilots showing feasibilities of different alternatives and variations of products and services connected to Smart Grid domain. Ones that show potential will be taken to the next stage, to a larger scale demonstrations of concepts. If the larger scale demonstrations show feasibility, the strategic choices about the direction of the Smart Grid development has to be made. As soon as strategy is clear, the large scale implementation can begin.

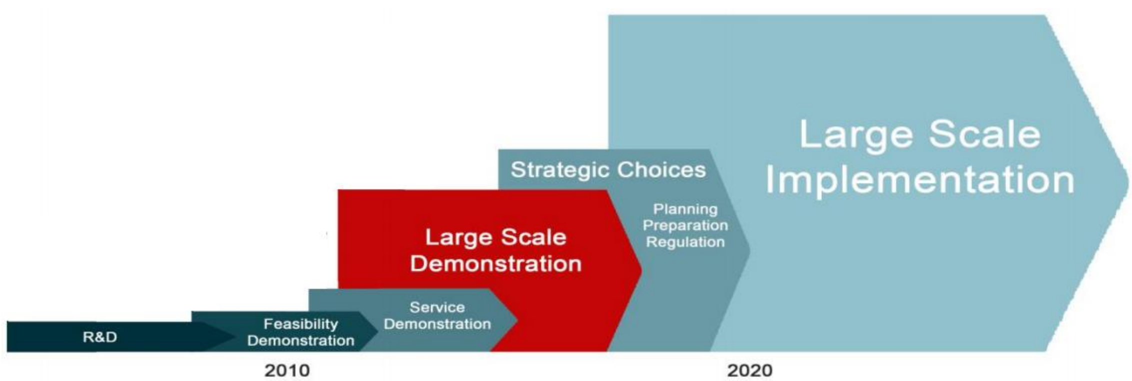

Figure 4: Projected development for Smart Grid. [54]

2.5 Smart Grid components

Smart Grid enables concepts to the energy field which have not existed before. A short description of the Smart Grid components are discussed in this section.

2.5.1 Distributed Generation

One major change in the energy system is the transition from centralised production to more geographically scattered production units. Historically the power grid has consisted of large centralised power plants, taking benefit from economies of scale and building them close to resources. The resources have not necessarily been close to consumption, resulting in long transmission distances of electricity. Also the amount of electricity generation has been predictable, and the production unit's location is known. The grid planning in this model has been relatively simple: the power flow is known both in size and the direction. With Distributed Energy Resources (DER), the location and power flow correlates with the weather.

Distributed generation consists of smaller electricity production units which are less site-specific. The size of the DG does not have exact range, but if it is defined to take into account small-scale production and micro-production, it can range from 2 MWs downwards. Generally Distributed Generation (DG) production units are considered as renewable energy sources: solar, wind, hydro and biopower. [50]

If DG starts to gain popularity widely, it creates challenges from traditional energy business perspective. As it is intermittent by nature and dependent on local weather events, both amount and location of production is not known accurately. Controllability of the system requires more automated solutions to keep under control.

2.5.2 Energy Storages

The value of flexibility in energy market will increase in the future, mainly because of the emergence of renewable energy. Renewable energy has often incentives to produce energy whenever possible, thus making the production structure more inflexible, causing the demand flexibility to become more valuable.

Therefore, storing energy has been a great interest in different R&D projects lately. Traditionally there hasn't been energy storages in the energy system. It has not been profitable to acquire energy storage, since the price of electricity hasn't had enough volatility to have incentive for demand flexibility. Initial investments for building energy storages are significant, there are losses when storing the energy and the coefficient of efficiency when transforming the energy from one form to another reduces the benefits.

The situation will change in the future. First, the battery technology is developing because of projects in hybrid and electric vehicles, which presses the prices of storages down. Second, changes in energy generation incurs costs to the strengthening of the electric network and less controllability implies to the increasing volatility of the electricity prices. The energy storages can help to balance the situation, both network-wise as well as market-wise. [17]

Energy storages have a role also in securing better functioning in transmission and distribution system level. Storages help the balancing of demand and intermittent generation, which has the benefit for both TSO and DSO. TSO can reduce the peak generation capacity investments. If energy storages are connected in distribution networks, it has an effect in grid topology as well as planning of the grid. In some cases, DSO might be able to defer the investments for strengthening the grid. [17]

The emergence of electric vehicles add another variable in the future's outlook. When the cost of the vehicles exceed certain point, i.e. it is beneficial in comparison to combustion engine, the change can be quite rapid. A large scale roll-out have a vast impact on the energy domain, which has to be solved in a very short time-frame.

2.5.3 Virtual Power Plant

Virtual Power Plant (VPP) is a concept where the energy production portfolio is created from the small-scale energy production units, resulting the generator actor from consumer-side. Usually the small-scale production's output is too small to be able to participate in wholesale electricity markets, so the production has to be collected to form a larger entity, a VPP. Markets see the VPP as an normal production unit, but in reality power plants location varies. This aspect makes the VPP virtual: it is created from small fractions, but for markets purpose it can be portrayed as an one large production unit.

Koeppel proposed the following definition of a VPP :

> "VPP stands for a concept of combining different types of renewable and non-renewable generators and storage devices to be able to appear on the market as one power plant with a defined hourly output." [48]

Two different types of VPP are identified: commercial and technical. The difference comes from the target market:

- Commercial Virtual Power Plant (CVPP) operates in wholesale markets. Revenues come from produced energy and the geographical location of production does not have any meaning whatsoever.
- Technical Virtual Power Plant (TVPP) offers ancillary services to system operators in order to maintain the stability of the grid. The production units should be in the same geographical area. [9]

VPPs ease the controllability challenges of the future if the DR, DG and energy storages (ES) can be combined under one umbrella and control with reason, i.e. production and consumption rates get the signal from either system-side or market-side.

Also by gaining the market access and the benefits regarding it, it works as an incentive for end-users to acquire more micro-generation. The public acceptance of the new products is important, since VPP require certain critical mass before it can fully benefit from markets. This requires the controllability hand-over from end-users own hands to some centralised actor, since at present DG is often controlled by the owners themselves.

2.5.4 Smart Meters

European Commission has defined the common functional requirements for a Smart meter. From the meter operators' point of view, the meter should allow a remote meter reading, providing the two-way communication between the meter and external networks for maintenance and control of the meter. It should also allow the readings to be taken so frequently that the data can be used for network planning, and enabling advanced tariff systems. [3]

The EU has mandated that 80% of households in the EU must have a smart meter by 2020. [67] This is an ambitious target and it has been questioned whether wanted effects can be achieved most efficiently through regulation.

Nevertheless, Automated Metering Management (AMM) provides crucial parts of the Smart Grid philosophy. An old adage says "You can't manage what you don't measure." This is exceptionally true when it comes to influencing the energy consumption. Without the knowledge about electricity consumption, a customer does not see the effects of its actions regarding energy efficiency. In Finland the roll-out of the smart meters have been on their way already, and the meter measures the hourly energy consumption and is able to take into account the end-users own energy production. Collecting this information means that customer can start using Demand Response, energy efficiency actions, energy storages and it lowers the bar for micro-generation.

Technically AMM enables the possibilities. None of these expectations will be realized without the active participation of the customer. The task of getting a customer to genuinely change its energy usage is easier said than done. It will require a comprehensive communication efforts in order to get a customer involved in this process. Communicating these ideas to the end-user and point out that it is worthwhile to participate will be the hardest task.

Innovative products are the key to increasing end-user participation. The starting point of attracting people's attention is that they are very passive about seeking information. It has to be done as easy as possible for them to acquire information on how to change the behaviour.

A good example is from a retail company Helsingin Energia, which has a web-service called Sävel+, where one can follow the energy consumption in different time-scales, resolution ranging from a year to an hour. In Figure 5, an example from the User Interface is shown.

The application does not provide the data in real-time, but in a few days delay. The application also gives reference values to other houses with similar conditions, and provides the comparison of end-user's own consumption. It is first of its kind in Finland, so there is room for improvements from ICT-perspective. Nevertheless, it is a first step to the right direction and sets the starting point about the possibilities in service sector. Many of the new services can be introduced only when a real-time

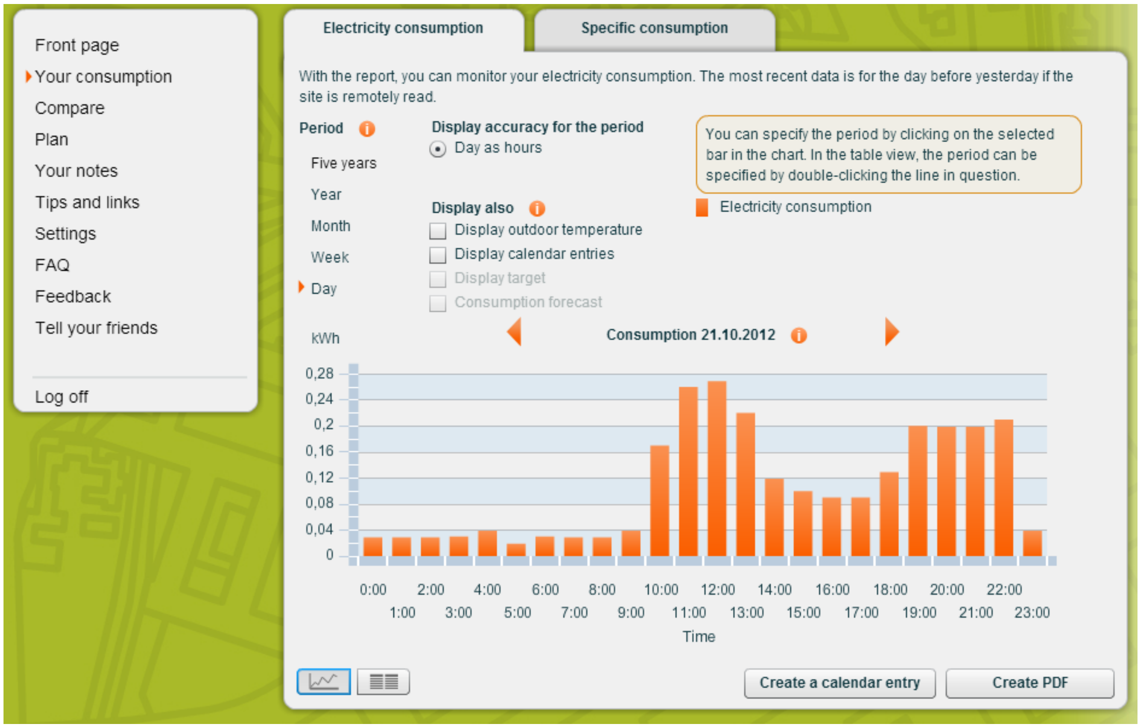

Figure 5: Author's energy consumption 21.10.2012 in Sävel+ application. [32]

consumption data becomes available, dynamic tariffs for instance.

2.5.5 Demand Response

The price of electricity varies constantly in the wholesale markets, depending on the amount of supply and demand at each moment but the retail customers usually see flat priced electricity. The price signal does not come through from the markets, so the customers do not have any incentive to change their electricity usage to more reasonable, optimal way.

Before, this disconnection from market signals didn't matter as much as now and the flexibility for electricity systems came almost solely from the power production side. Now with more rigidity in power production that renewables introduce and the technology development in load control systems has brought up the Demand Response as a potential solution in balancing the demand and the supply. [14]

2.5.6 Distributed Energy Resources

Term Distributed Energy Resources (DER)is a term that is used usually when there is a need to emphasize the overall effects of the production and consumption in lieu of only production. Generally DER consists all of the above: distributed generation, energy storages, virtual power plant, demand response.

From the overall benefits of these new concepts, Shandurkova et al. [9] listed as in Table 3.

The following Table provides an extensive look on the potential benefits. It has to be noted that there is no single way to implement DER. It is a complex concept with vast amount of variables that are dependent on economical, regulated, political, as well as technical development factors. The positive benefits have their boundaries and certain requirements must be fulfilled before the full potential can be achieved. More detailed briefing can be found in [9] and [17].

Table 3: Benefits from DER to different stakeholders. [9]

Stakeholder	**Benefit**
Owner of DER (prosumer)	Capturing the value of flexibility Increased value of assets through the markets Reduced financial risk through aggregation Improved ability to negotiate commercial conditions
Network operators TSO and DSO	Increased observation over DER for operation through aggregation Advantage gained from flexibility of DER for network management Improved optimization of the grid investments Improved coordination between DSO and TSO
Supplier and aggregator	Creation of new offers for prosumers Mitigating commercial risk
Policy makers	Cost effective large scale integration of renewable energies while maintaining system security Opening the energy markets for small scale participants Increasing the global efficiency of the electrical power system by capturing flexibility of DER Facilitation of renewable targets and reduction of CO_2 emissions Improvement of consumer's choice
Society	DER will contribute to a more economically attractive electricity cost, thus contributing to a more competitive market Improved power services, or reduced economic cost of current services Disruptions and cost of added transmission and distribution infrastructure are delayed

3 Electricity Markets

Electricity markets and its best conceivable structure has recently been under discussion. In the past the electricity was considered clearly to be a monopolistic business, since the production has economies of scale and is very capital-intensive. The delivery of electricity to the end-user is completely dependent on vast, expensive transmission and distribution grid. These factors made the business to be controlled by few large actors.

As the world has developed and the collaboration among countries has increased, the electricity markets are pushed from national markets to larger entities. The political environment has also been intriguing driver for establishing transparent electricity markets. On one side, interest in re-arranging the public services has boosted to form transparent market environment which would do innovative, market-based solutions and find the balance through these mechanisms. Second, the integration of all common internal markets have been a target for European Union. The development of European electricity markets is influenced greatly by the new energy policy of European Union. [18]

With liberalization of electricity markets, the product, electricity becomes a commodity in the same way than for instance oil, grain or coffee. As in all the other commodity markets, the outcome is the wholesale market and a retail market with three usual players: producers, retailers and end-users. With electricity, a more sophisticated trading pattern takes hold and new players emerge as well: the traders and the brokers. [22]

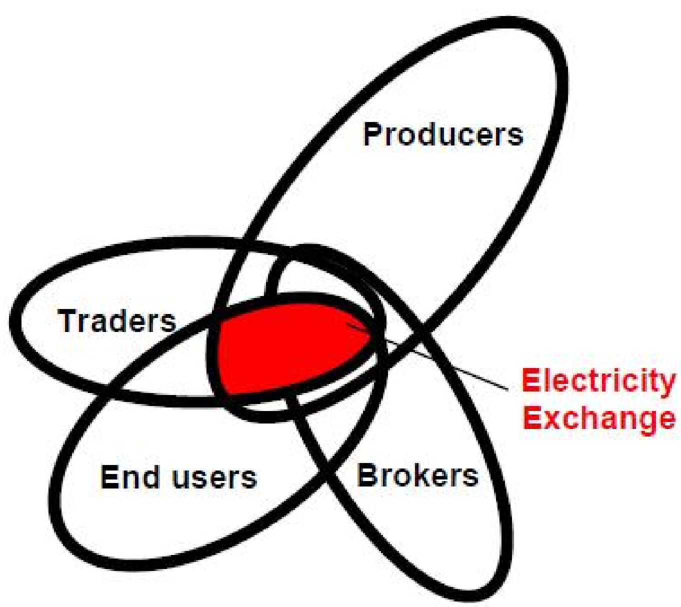

Figure 6: Actors forming the electricity exchange. [22]

A trader is the entity which owns the electricity while the trading process is running. How the electricity ends up to the end-user can have several routes, for instance trader can buy the electricity from the producer and sell it to the retailer, or buy from retailer and sell it to another.

Brokers act as an intermediary player, negotiating purchases in return of a fee or commission. A broker does not own the asset itself. A retailer can ask the broker to find a producer who will sell given amount of electricity at given time.

3.1 Peculiarities of Electricity Markets

The electricity has very interesting characteristics in its very nature. The most interesting oddity which distinguishes it from other commodity markets is that it cannot be stored in large scale, at least not very cost-efficiently.

To some extent electricity can be stored for later use by using pumped-storage hydroelectricity systems and furthermore the flow of water can be adjusted to some extent to have more production at times of high consumption, but even with these two exceptions, electricity is hardly comparable to other commodities like minerals or oil for which the storage capacity is many orders of magnitude greater when compared to the average volume of consumption. [25]

New kind of energy storages have been much of interest in energy business recently but so far, the energy storages are in very early stage of R&D with lot of uncertainty on when it will become feasible in large scale, or ever.

Since electricity cannot be stored, the demand and supply has to be in balance every moment at given time. Consequently, demand and supply vary continuously. Even small changes in load or generation can cause significant changes in prices. This creates several underlying principles and explains many aspects we see in the electricity field.

The next four sub-chapters will examine these principles.

3.1.1 Seasonality

Due to the real-time balancing and the cyclical demand the electricity prices are very cyclical as well. This seasonal component is very dominant in electricity markets and different patterns of it can be found in the timespan of a day, a week and a year. [26]

Day-level and week-level differences arise from the pattern of how society works.

Yearly-level seasonality arise due to changing climate conditions, where the temperature changes and amount of daylight set the pace to the demand. Depending on what is the production structure markets, also supply-side experiences climatic changes. For instance the Nordic market is very seasonally fluctuating in supply side since the production has a vast amount of hydropower, which is heavily dependent on amount of rain and snow melting.

3.1.2 Volatility

The volatility of market prices in energy markets is very high. It is completely in different scale (100 – 500%) compared to currencies (10 – 20%), interest rates (10 –

20%) or compared even to the volatility of stock rates of return (20 – 50% volatility). This means that markets carry high risk to operate. [5]

This can be traced back to the lack of storages and transmission capacity. Without inventory short-term's precise balancing is hard to achieve.

With more renewable energy, volatility is expected to rise even further because of the difficulties in controlling the production level.

3.1.3 Mean reversion

In comparison with most financial markets, another fundamental difference in electricity markets is that it is mean-reverting. The term mean reversion is a concept to describe a stochastic process which has a tendency to remain near, or tend to return over time to a long run average value. [42]

The explanation for the mean reverting nature of the electricity spot prices get into the marginal costs of production and demand fluctuation. When the electricity demand increases, the generation facilities with higher marginal costs of energy production emerge on the supply side, which pushes prices up. As the demand decreases to normal levels the profitability of these this more expensive production modules disappears and they will be turned off, resulting the prices to drop. This kind of operating structure supports the thesis that there exists mean reversion in electricity spot prices. Empirical studies show also that hourly electricity prices are mean-revert around an specific hour mean level. [27]

3.1.4 Peak Prices

In addition to previous oddities, the electricity markets experience infrequent, unpredictable peak prices. Price peaks can be a result from many different factors. Weather can create a high demand, the system can experience outages in supply side or scarce capacity can result in very high prices in certain areas. [28]

If the price is not restricted, negative prices can occur as well. RES' generation is made beneficial with subsidies, like the feed-in-tariff which guarantees certain compensation level to its owner. This means that it is always beneficial to produce electricity. Due to the operative costs of nuclear power plants, it is not preferable to ramp down the generation for the short time periods. With this stiffness of energy production, a situation might occur that the generation exceeds the demand and causes the price of electricity to go to the negative side. In countries with significant amount of RES, this has been experienced.

3.2 Nordic Electricity Markets

The Nordic electricity markets consists of Finland, Sweden, Norway, Denmark, Estonia and Lithuania. These previously national markets opened up for competition in generation and retailing, and integrated into a single Nordic electricity market between years 1991 and 2000 making them one of the first free electricity markets in Europe. Estonia and Lithuania joined to the Nord Pool Spot in 2010. [22]

The energy is traded in financial market NASDAQ OMX Commodities Europe and in physical energy exchange Nord Pool Spot AS. NASDAQ OMX Commodities Europe offers the market place for derivatives contracts with different time scales, from days up to six years. Financial instruments are used to manage risk and guaranteeing electricity's price in the future. Nord Pool Spot AS provides the platform for physical power trade. It operates on day-ahead markets, Elspot, as well as intraday market, Elbas. In Figure 7 the countries and the bidding area division of the Nord Pool Spot Power Exchange are introduced.

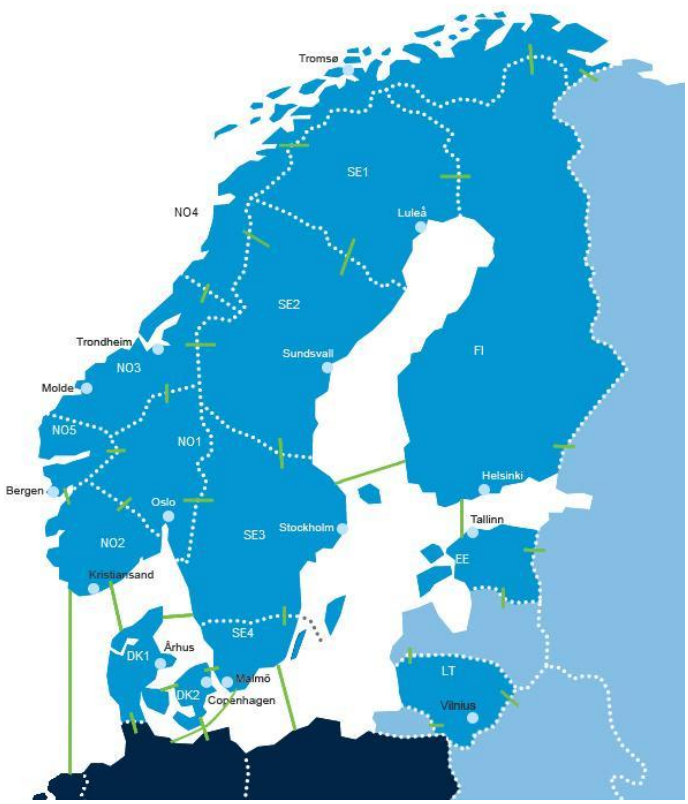

Figure 7: Nordic electricity markets and the bidding areas. [31]

As mentioned, the Nordic electricity markets are one of the first free electricity markets. Liberalization of the electricity markets means that vertically integrated electric companies unbundle the transmission part, which is seen clearly as monopolistic business, and production as well as retailing to separate entities. Transmission and distribution are strictly regulated entities in order to avoid misuse of monopoly position. Generation and Retailing activities enter the open markets, which brings them under competition. Competition makes the processes more effective and the customer gets the benefits of enhanced situation. Unbundling is illustrated in Figure 8.

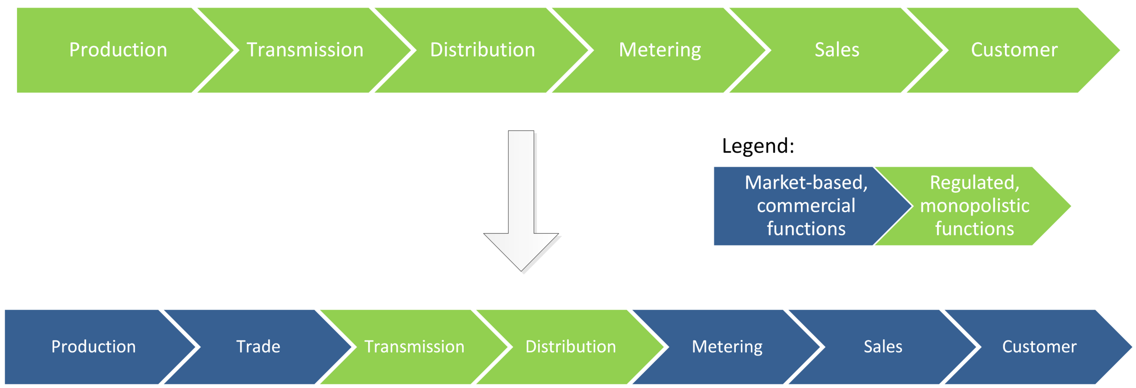

Figure 8: From integrated electric utility to unbundled electricity market. Adjusted from [53].

3.2.1 Elspot market

Elspot is a day-ahead closed auction where hourly power contracts are traded for physical power delivery for every hour during the next day. The members place their orders, hour by hour, to Nord Pool Spot's web-based trading system, SESAM. The orders can be sent up to 12 days ahead and the gate closure for the orders for the next day is at 12:00 CET. [22]

Elspot is an "energy-only" market, meaning that the exchange concerns only energy (MWh) without taking into account the capacity (MW). When all the participants have submitted the orders, the prices for every hour can be determined. By combining different offers and bids, the supply and demand curve is formed, and the intersection point between market and supply curves is the system price of the current hour. Figure 9 illustrates the forming of a system price.

When calculating the system price, possible transmission capacity constraints are neglected. In reality there is often restrictions in capacity between the areas, and the Elspot market is divided to several price areas which are formed by taking the actual transmission capacity into account. [22]

3.2.2 Elbas market

The adjustment market Elbas is a continuous intra-day market including the Nordic region, Germany and Estonia. Elbas functions as a balancing market for Elspot: it has an important role for risk reduction as well as provides the potential for making profit. The balancing trades can be done until one hour prior to the delivery. Elbas markets offers the alternative solution to minimise participants' imbalances after the gate closure of a day-ahead markets. Together with Elspot they create an efficient Power Exchange structure.

Trading takes place every day and the markets stay open until one hour before delivery. Price structure is based on first- come, first- served principle, lowest sell price and highest buy price comes first, with no attention to when the order is

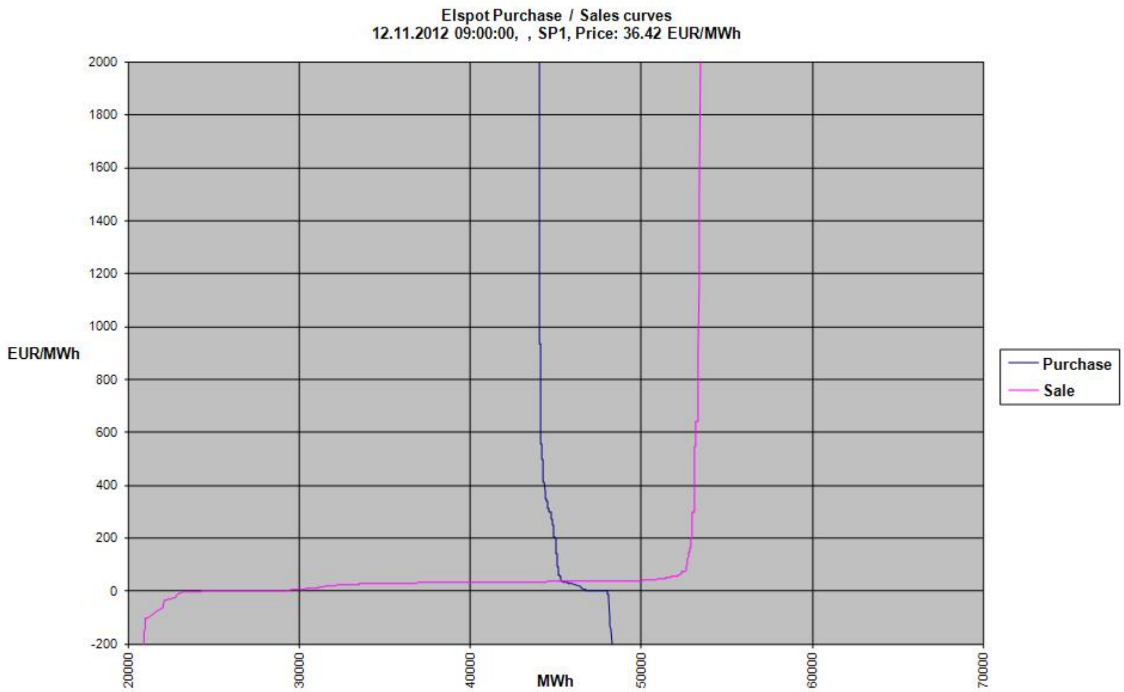

Figure 9: Formation of a Spot-price. [22]

placed. [22]

3.2.3 Market competition

Even though the Nordic Markets have a lot of participants, according to Finnish Competition Authority the market still has oligopolistic features. From production-side, entering the markets is difficult since heavy investments are needed in order to achieve enough production to meet the minimum requirements for market participation. Also the regulation obstacles for building new power plants are strict, making it challenging to build new generation. [6]

Although some remarks about competition, a general opinion is that electricity markets in Nordics work well. Nordic electricity markets are fragmented among large amount of players, introducing the competition to the energy domain. In Figure 10 the dispersion of different parts of Nordic electricity business is illustrated. With fragmentation, it is more difficult for a single actor to affect the price of electricity by its actions.

This has not been the case previously. Before, every national markets were dominated by one large player, for instance Vattenfall had over 50 % market share in Sweden before uniting the national markets to one entity. Now, with integrated markets, the combined market share of 4 largest producers is close to 50 % (See Figure 10). From competition standpoint, Nordics are close to a single market. [30]

Over 70 % of electricity consumed in Nordics is exchanged in Nord Pool, which ensures the high liquidity of the markets. [22] Also the high volatility that has been

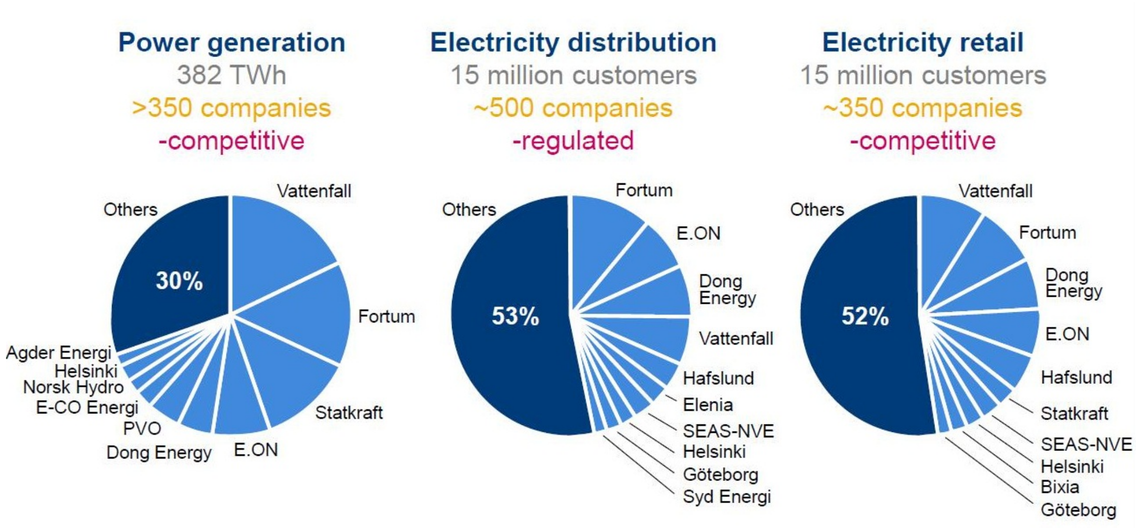

Figure 10: Fragmentation of Nordic electricity markets. [68]

experienced in electricity prices is a sign that signal from changes in demand and supply go through to the markets. From a social point of view, it is important to ensure that the market prices reflect the production's marginal costs. When the system is dominated by hydropower, exploiting the market power is not easy to detect, since generator has the possibility to either use or to store water in a reservoir. This decision is made on factors such as forecasting of water levels and length of winter season for instance. For outside observer it is hard to say whether the decision is reflecting the use market power or expectations about future's climatic situations. [30]

The transparency requires that open competition is really happening, and the amount of Over the Counter (OTC), bilateral agreements should be set under the competition as well. Still, there are signs that market participants are still in unequal position because of asymmetric information between large and small players. With size comes benefits, the actors with large production or consumption resources have more detailed and real-time data on the market compared to ones with more limited resources. [28]

The gains from open competition model are seen as beneficial in the long run. But in order to realize these gains, market has to monitor the situation whether the open competition actually is happening. The barriers for entry both in generation and retailing whereas bringing even more innovative actors has to be as low as possible. [34]

3.2.4 Special characteristics of Nordic Electricity Markets

Nordic electricity markets have pioneered the unbundling of the generation and retail business from the natural monopolistic infrastructure side. Before, the monopoly rights and self-sufficiency requirements led to building excess capacity. The aim of the electricity market reform was to even the price differences in different regions, add transparency to the markets and to remove the over capacity thus improving the overall efficiency of the markets. [69]

Unbundling has brought the wanted effects: it has increased the competition on both wholesale and the retail markets, causing the diminishing of the profit margins. Also the overcapacity of production has been reduced, increasing the power industry productivity.

Still, it has to be noted that even though positive developments in energy industry, the public opinion has been less enthusiastic about the electricity market reform. Main reason for this has been the increased retail electricity taxes which cause households to pay more for the electricity than before. Also the complexity of the billing is seen as too complicated to understand. These are more external factors and political decisions rather than a sign of badly functioning electricity markets, but it is hard to communicate to large audience. [30]

Nordic electricity markets have certain characteristics in its structure. The structure has designed to be fitted in conditions Nordics have, but several aspects can be adopted generally to other markets as well.

Four points is recognised why the Nordic electricity market has succeeded:

1. A simple but sound market design, to a large extent made possible by the large share of hydropower.

2. Successful dilution of market power, attained by the integration of the four national markets into a single Nordic market.

3. Strong political support for a market-based electricity supply system.

4. Voluntary, informal commitment to public service by the power industry. [30]

Points 1 and 4 are characteristics of Nordic society, but the other two points are general and worth striving for in other markets as well. Next, the short comments about the characteristics follows.

Figure 11 shows that in Nordics there are vast amount of hydropower, which is not usual in other parts of Europe.

Main difference to the situation in Europe is that hydropower-dominant electricity systems tend to be energy-constrained rather than capacity-constrained. The level of water reservoirs, which work as a ”electricity storage”, is the essential feature in the system rather than amount of production capacity. With cold winters the electricity consumption varies more in the Nordic countries compared to the situation in Europe. This has required to build a strong network in the first place. The whole approach for the situation is different, since only lately with DER, there has been increasing pressure for grid strengthening in Europe. Hydropower has many useful characteristics in it. In comparison to fossil fueled power plants, the start-up costs of power plants are insignificant, which in turn gives the right signals for the efficient allocation of resources.

Point 4, the power industry's voluntary commitment to public service, is also seen as area-specific for Nordic countries. The atmosphere around the electricity

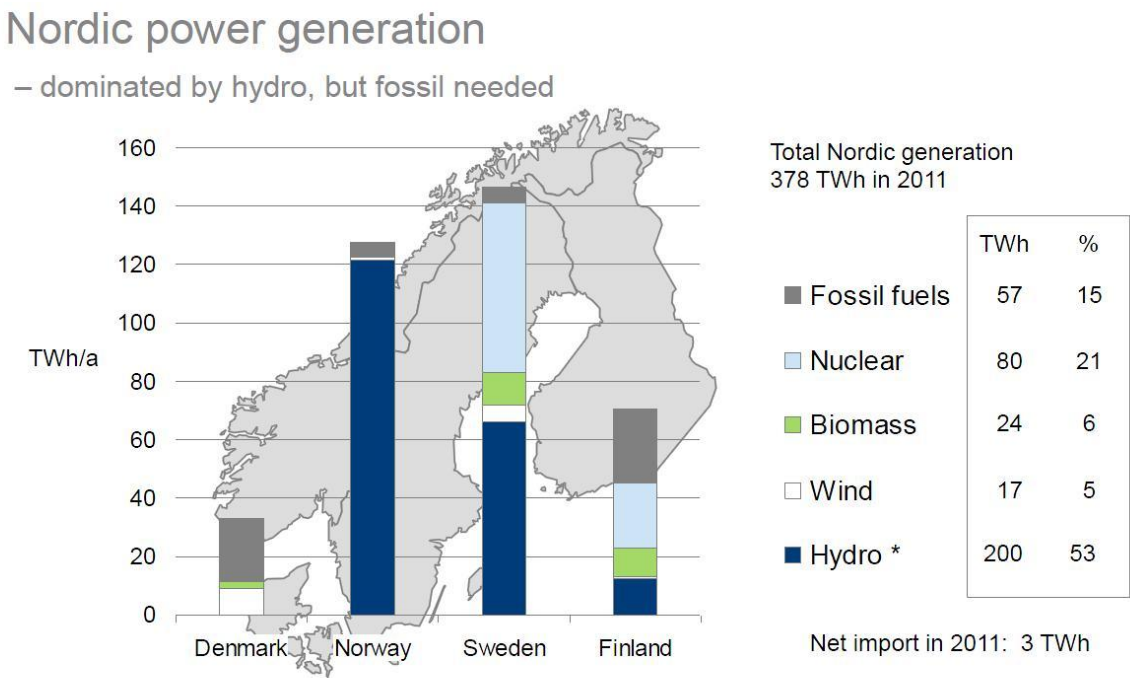

Figure 11: Nordic Power Generation. [68]

environment is still careful among the actors, with fear that if there will be scandals concerning using market power, it will create more regulations and the change the direction back to the regulated, old system. [30]

The general points from the Nordic experiment that can be implemented to larger scale are quite self-explanatory: Dilution of market power as well as continuing political support with courage to stand behind the long-term strategical decisions.

For Nordic market, the unbundling has brought the situation what was pursued. It has decreased the amount of unused capacity to the markets. Overcapacity doesn't exist anymore, there has been a few minor power shortages but so far the markets have been able to take care of it. [33]

3.3 Roles of Different Players

3.3.1 Generator

U.S. Energy Information Administration (EIA) defines the generator as

> "A regulated or non-regulated entity (depending upon the industry structure) that operates and maintains existing generating plants. The generation company may own the generation plants or interact with the short-term market on behalf of plant owners. In the context of restructuring the market for electricity, the generation company is sometimes used to describe a specialized "marketer" for the generating plants formerly owned by a vertically-integrated utility." [41]

3.3.2 Transmission System Operator

TSO is an actor who is responsible for the maintenance and operation of the High Voltage Electricity Transmission System. This carries power from central power stations to the Distribution System, where responsibility transfers to the distribution system operator (DSO). The business is regulated due to its natural monopolistic nature.

Transmission System Operator is the backbone of the whole electricity system. It is responsible of maintaining the physical electricity delivery. Nordic Energy Regulators (NordREG) [15] identifies the core tasks of TSOs accordingly:

1. Ensure the operational security of the power system
2. Maintain the momentary balance between demand and supply
3. Ensure and maintain adequacy of the transmission system in the long term
4. Enhance efficient functioning of the electricity market

Apart from these common core tasks, TSOs may have some other duties that are not included in these tasks about system responsibility, depending on different legislations in different countries.

NordREG have defined that TSOs act in three different roles in the Nordic electricity framework. They are as follows:

- Transmission operator
- System operator
- Balance settlement responsible

Transmission operator is responsible for tasks 1. and 2. Task 3. is fulfilled when TSO works as a system operator. The task 4. concerns all of the roles introduced. [15]

Other important tasks are to secure the functional, transparent and open electricity markets.

3.3.3 Distribution System Operator

Distribution system operator (DSO) manages and operates a distribution network for energy (electricity, gas, heat) or water. DSO transports the electricity through high voltage, medium voltage and low voltage distribution systems. In the competitive electricity market the distribution of electricity is usually a natural monopoly controlled by the regulating authorities. [47]

The DSO has a central role as a neutral market facilitator, ensuring the functional markets by securing the stability of the network system. Through the platform the DSO maintains, customers benefit from the offering of the open markets where the commercial players are in competition.

3.3.4 Retailer

Retailer is an actor in the competitive electricity market that connects retail market customers with the wholesale market. A retailer in electricity domain acquires the electricity from the wholesale markets and then sells it forward to the customers with a profit. Because the electricity is acquired from the power exchange (PX) day before the customers' forecasted consumption, the retailer carries the risk of the imbalances of the bought and sold electricity.

As the electricity world is in transition to more complex structure, retailer can offer also services with energy saving schemes as well as adding renewable energy to the small customers.

3.3.5 Customer

A customer has a contract with a retailer, who provides the electricity needed. A customer may or may not be the consumer of the electricity, but usually with a customer, it is implied that he usually is the end-user of a commodity electricity. They are the users of the energy supplied and do not pass it on to further customers.

3.3.6 Balance Responsible Party

Each party operating in the electricity market must take continuous care of its power balance, i.e. the party must maintain a continuous power balance between its electricity production/procurement and consumption/sales. In practice, an electricity market party cannot do this by itself, which is why it must have an open supplier which balances the power balance of the party. In Finland, a party whose open supplier is Fingrid is referred to as a balance responsible party (BRP).

The open delivery between Fingrid and a BRP is agreed upon through a balance service agreement, whose terms are public and equal to all. Upon signing the balance service agreement, the balance responsible party obtains the open electricity delivery and also the services related to imbalance settlement between the balance responsible party and Fingrid as well as an opportunity to participate in the balancing power market. [66]

4 Future Trends of Energy Markets

In order to analyse the changes to the players' roles and responsibilities, the drivers for the future development has to be introduced. In this Section there's an outlook for the integration in European level and new, emerging players are introduced.

4.1 European electricity market integration

The European Union concentrates on creating the integrated, internal energy markets. The designed market structure would include flexibility and higher transparency compared to the situation nowadays. It is needed to ensure a favourable and secure energy supplies for industry and households, as well as to tackle the climate and energy challenges. European Union's Energy Strategy aims to fully integrate the different energy markets into one by the end of 2014. By combining the fragmented markets into one entity promotes better competition, better products and results in more secure supply. [70]

Initial integration is in target at 2014, but longer time scale scenarios are examined as well. Designing the functional market for Europe, the following aspects are seen as important features to be taken into account:

- Over-all system costs
- Volatility in the electricity prices
- Generation mix
- Geographic location of generation and demand
- Effects on network expansion
- Demand response
- Trade-off between market risk and regulatory risk [63]

The increase of renewable production creates the change in the generation mix. More volatility is introduced and it is to consider whether it is possible to rely on renewables due to its intermittent nature. Intermittency creates the situation where it is needed to build an excess capacity to secure the required level of security of supply. Large volatility in generation levels puts the transmission network under stress.

As there is excess capacity of renewables with low marginal costs, it presses down the price of electricity, causing the traditional power plants investments' payback times to grow, thus making them less attractive.

As seen, two crucial challenges have been identified concerning the capacity of distribution network and the generation structure. Moreover, intermittency result to more volatile electricity prices. This is a fact that is hard to explain to the public opinion and media since electricity is seen as a commodity which is assumed to have little variation on its price.

Public opinion and media attention towards electricity has significant impact when deciding the target model. If there is a consensus that volatility of the electricity prices is not acceptable, political decision can steer the market model to less optimal, but less volatile situation. How the electricity markets evolve depend greatly from policy-makers. [63]

4.1.1 Market models

Different market models can be created by taking different aspects into account, e.g. price formation, regulatory decisions, level of competition. Usually two different market models are introduced by taking the focus on the network capacity. The question on how well the system is capable to respond to demand of the market is crucial. EU's strategy at the moment is to build a market platform which enhances the competition over different nations' borders, which means vast investments to the transmission networks. Another option is that markets adapt to the transmission capacity. In Figure 12 the main differences of two scenarios are depicted.

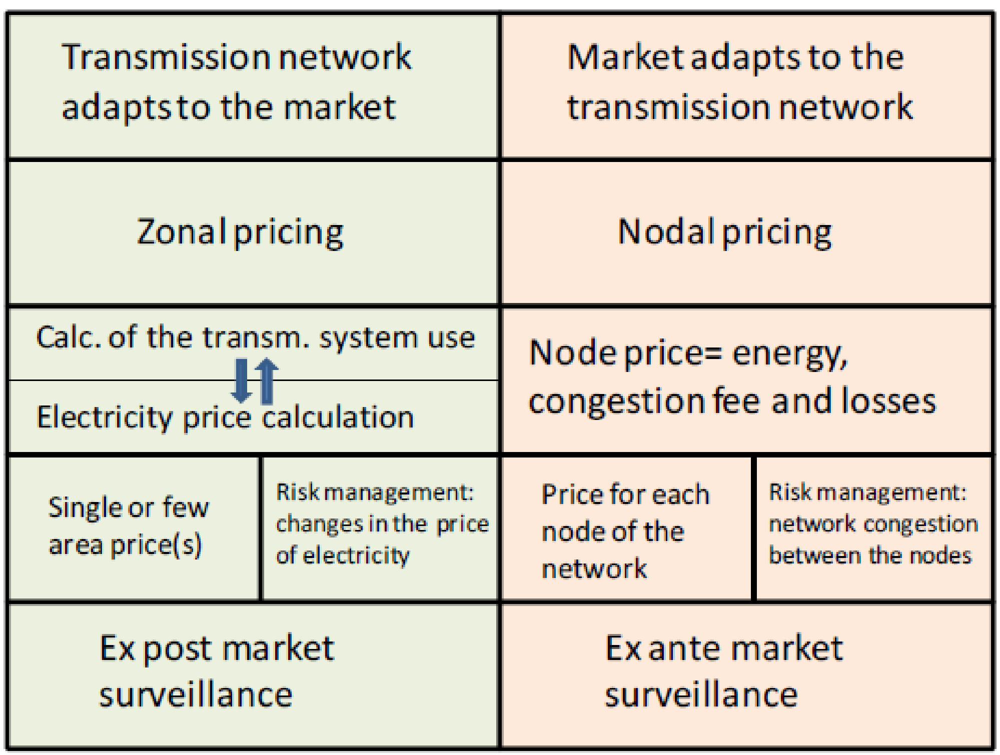

Figure 12: Proposed models for markets. Left, Open markets (Scenario 1) and on right, Capacity markets (Scenario 2). [18]

The transmission capacity is the determining factor between the models. If there is enough network investment plans, the markets can be integrated in such a way that there is no restrictions among areas, thus making the open market model possible. Without strengthening the network, it becomes a bottleneck which the market has to adapt to. This implies to the possible power shortages, where capacity markets try to bring relief by building additional power capacity. Both scenarios are described in more detail in the next sections.

4.1.2 Open markets (Scenario 1)

Vision of Scenario 1 potential relies mainly to two things: the sufficiency of transmission capacity and the active engaging of the demand side. These two factors open the free competition in the electricity markets. Without bottlenecks in a transmission network a large price areas can be formed, equalizing the price of electricity in large areas. The need for regulation is carried out reactively, as the areas are so vast, the risk for exploiting the market power diminishes through increased number of competitors in wholesale markets.

With active demand side management the price setting power from the generators is limited, causing more optimal allocation of generation resources. This leads to a correct marginal costs from production to reflect in market price.

In Scenario 1, the price calculating method is different from the Scenario 2. TSOs are responsible to provide information about available transmission capacity, and the Power Exchange creates the price from the sale and purchase orders. [18]

4.1.3 Capacity markets (Scenario 2)

Another scenario forms when there is constraints in the transmission system. Constraints split the markets to small fragments, separate networks with generation and consumption of electricity. This causes the price of electricity to vary locally, meaning that the regulation differs from the Scenario 1. Locational marginal pricing poses a threat to a use of a market power. This means that the need for market regulation is much more strict to avoid the misuse of positions. In nodal pricing model the generator's bids are monitored and the prices of electricity are usually restricted to certain limits. Restricting price can be a questionable act, since the high electricity prices give the signal for the need for more production capacity. With restriction this signal doesn't come through to the markets, and alternatives are sought from other solutions. For instance, there can be a separate capacity markets, which guarantees more investments to the new capacity, and the generators get compensation for its existence, whether it is used or not.

Another problem which comes with price restrictions is the losing incentive for demand flexibility. If the price does not go through correctly, there is no need for curtailing the electricity when there is a scarcity in generation. [18]

There is a danger that markets are not liquid and transparent and in addition the integration of different markets suffer when these kind of instruments are taken in use, even though there would be more transmission capacity planned in the future. European Commission has taken a stand against this. Some of the Member States have introduced a plan to initiate these plans for securing the sufficient generation capacity through alternative instruments than "energy-only"-markets, i.e. initiating capacity markets. European Commission sees that if the capacity mechanisms are not designed well, are introduced prematurely and without satisfactory level of co-operation at EU-level, there is an ample risk of distorting the optimal market situation, bringing counter-productivity to the markets. [70]

Effects of capacity markets have been debated mainly qualitatively, but also simplified scenarios with quantitative analysis have been introduced. Two different alternative cases has been taken into account: EU-wide capacity markets and capacity markets only in Germany. [72]

EU-wide capacity market vs capacity market only in Germany

In Figure 13 the comparison between the base case (no capacity markets) and EU-wide capacity markets is presented. As it is seen, the nature of capacity installed has to be such that it provides the secure generation when it is needed. Additional capacity that is needed to be installed would be conventional energy production, which is against the targets of the EU's 20-20-20-plans.

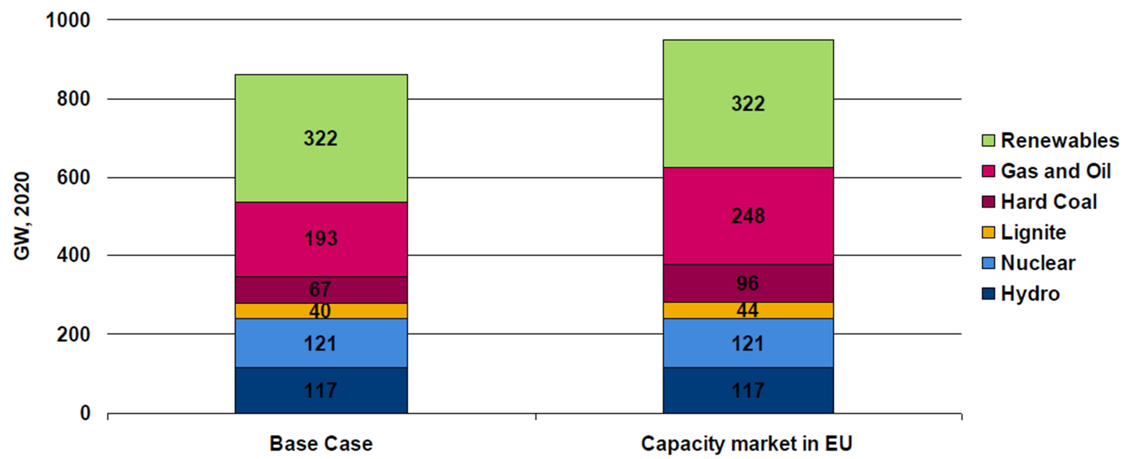

Figure 13: Effect of capacity markets in EU-level. [72]

Energy demand is expected to experience only modest increase in European level by the year 2020. Additional power capacity for the sake of keeping the prices even is not what would be optimal from the society perspective, nor is the will of EU's strategy.

In Figure 14 the comparison of capacity market in EU and only in Germany is shown, from Germany's point of view.

As the Figure suggests, that introducing the capacity markets to whole Europe, looking at the pattern of exports and imports it would not have radical effects, but it would result in some changes in power flows, for instance the Netherlands would change from net importer to net exporter. If the capacity markets are adopted only in Germany, it starts to have an effect to the patterns. There would be a significant changes in imports and exports patterns, leading to a significant increase in exports, which implicates larger revenues for the German generators. From Nordic point of view, the exporting to Central Europe diminishes slightly, resulting in reduced system price in Nord Pool Spot.

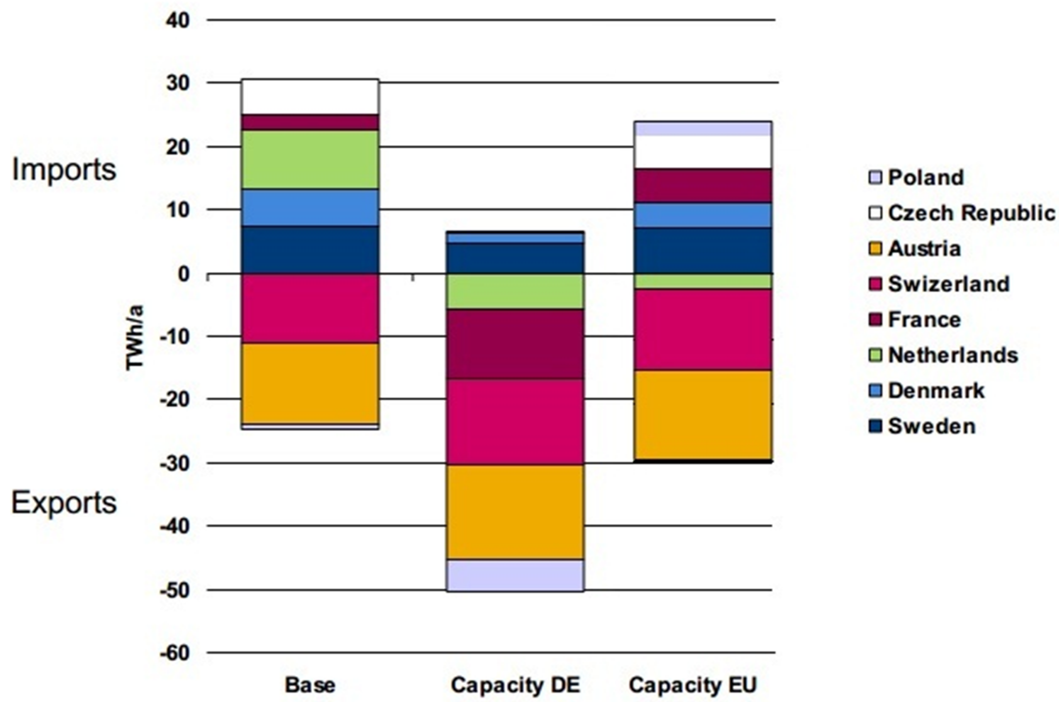

Figure 14: Impact of capacity markets in cross-border flows. [72]

In summary, threats and opportunities about the possible effects of capacity markets are introduced in Table 4:

4.2 New Stakeholders in the Energy Markets

As there is a trend of adding more DER, making the generation structure more inflexible in addition of more automation and ICT provided inside the energy system, new players emerge to answer the needs of changed environment. In this section the most prominent new stakeholders are introduced. The potential for these players is high, changing the outlook of the business.

4.2.1 Prosumers

As one of the most prominent changes in the electricity business is the uprising of renewable energy sources and distributed generation's role in a sustainable solution to the energy field. Political support has ignited the small scale production to be more profitable.

This has big impacts on the role of the consumer as we know it. Incentives for renewable energy sources in addition to price drop of the renewable technologies, a small consumer, household, can start to produce its own energy and even become a producer with excess production.

Table 4: Challenges and opportunities of capacity markets. [71]

	Threat	**Opportunity**
Regulation	Investments do not depend on the markets	Safer-income helps to fund investments
Market integration	Different systems in different countries, distorting competition and reducing efficiency	Incentives are already national
Demand flexibility	Larger proportion of fixed costs and more consistent prices doesn't provide incentives for DR	Fixed payment beforehand can enable demand flexibility
Competitiveness	Chances for inefficient markets, expensive for customers	Can allow new players in the field
Loss of the exchange liquidity	Larger proportion of fixed income reduces the incentive to hedge	Smoother rates reduces the need for hedging

With own production, the consumer's role turns into two-folded: a consumer is both on demand and supply side. This new emerging term a "prosumer" can be defined as an economically motivated entity that:

- Consumes, produces, and stores electricity and energy in general.
- Optimizes the economic and to some extent the technological, environmental decisions regarding its energy utilization.
- Becomes actively involved in the value creating effort of an electricity or energy service of some kind. [9]

Today, the role of the energy-producing consumer is still a new phenomena and very limited in scale as well as importance. Nevertheless, large-scale deployment of prosumers can happen quite rapidly so it is of great importance to examine the effects proactively.

Questions arise about the role of this newcomer in the energy environment, where large companies play a dominant role. The concept is not easy to position in the value chain of the complex energy markets. In Figure 15 the value network where a prosumer has to operate is illustrated.

The main challenge is to monetize this small-scale production. In order to bring the benefits from the concept, intelligent energy-management services has to be designed and developed in this constantly changing, uncertain value network. The basic starting point for the service design is that it should create value both to the customer and the other actors connected to it. [16]

It is not as straight-forward as it might sound, since there are several barriers concerning regulatory and technical issues such as what kind of systems are used to

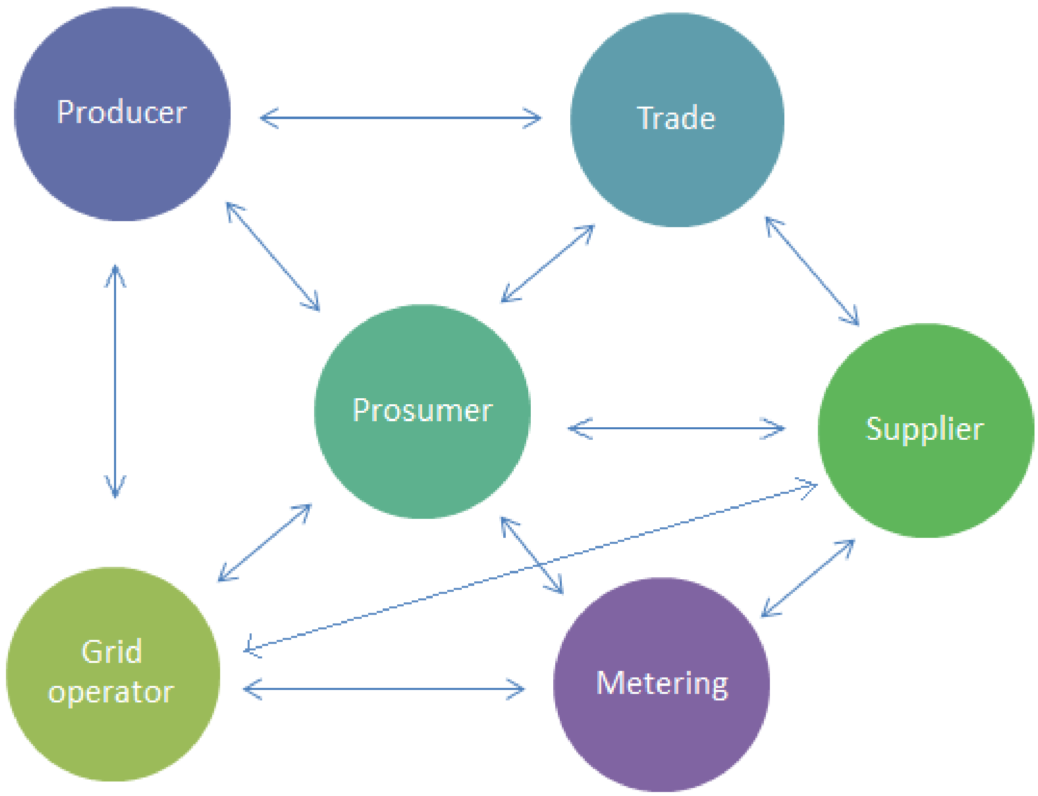

Figure 15: Prosumer in a complex value network. [16]

determine the consumption and production, whether netting of the values are used or are they measured separately. [49]

Another aspect to notice is that the prosumer is quite small considering the energy and power it can produce. A single prosumer cannot participate to wholesale markets very efficiently since the asset from single microgeneration plant is very marginal. Alone it doesn't have very much benefit but if there would be an actor that can collect this excess power from a mass of prosumers, it starts to matter. This is where the so called aggregator concept is seen useful, which is discussed in the next chapter.

4.2.2 Aggregator

The concept of an aggregator tries to activate the demand-side which helps to solve the fundamental problems that are connected to the nature of the electricity: storaging and flexibility.

An aggregator collects the customers' demand flexibility and excess generation of electricity, optimises the electricity usage behaviour, and offers these resources to the market. Ikäheimo et al. [45] defines aggregation as

> "An aggregator is a company who acts as inter-mediator between electricity

> end-users, who provide distributed energy resources, and those power system participants who wish to exploit these services."

From collected small-scale production and demand flexibility an aggregator can create a Virtual Power Plant (VPP), through which the resources can be centrally controlled. Centralised control enables the optimal use of the resources.

In order for aggregation for small-scale to take on hold, an aggregator has to consider many practical aspects when designing the service it offers. An aggregator has to have a vision about

- Customer segments, which can provide the needed distributed energy resources (DER) and demand response (DR).
- Knowledge about the customers' load profiles and control responses.
- The nature of DR, understanding what is the need for it in different markets.
- Devices and ICT gateways what is needed to deliver the load control.
- Decision abot the contracts that will be offered for the customers, creating the right incentives to attract the customers. [21]

An aggregator acts as an intermediate between the two different markets. The difference to usual business models comes from the fact that the consumers, households, are the source of the asset that aggregator sells forward to its customers, like the wholesale markets, TSOs, DSOs and retailers (if an aggregator is not retailer himself). Unlike in normal business, the relationship to the customers (TSO, DSO, markets) is not significant but the marketing effort is done in supplier side, i.e. end-users of electricity. Figure 16 clarifies this exceptional business logic of an aggregator.

Looking at the latest disruptive services that have re-defined the business world, the main idea has been to create a platform that links together two distinct groups of users. For instance Google joins together web users and advertisers. These two-sided networks are called platforms. Two-sided networks differ from traditional market places in a fundamental way. In the traditional value chain the value has one direction. In the two-sided networks, cost and revenue can move to both directions, because the platform has a distinctive groups on both sides. The platform gets costs on serving both groups but it is also able to collect revenue from both sides. [12]

This is what an aggregator brings to the electricity world as well. The intriguing difference to present situation is that energy and revenue doesn't flow anymore only from consumers to other participants, but the flows can change direction, according to the market situation.

So far, the aggregator companies has been in such a small scale that real-life examples from the subject remain unseen. Another large change to the markets is the introduction of demand flexibility. In the future electricity markets face the question that are there bids for both supply and demand, or is the demand taken as a constant, determined on the basis of a load forecasting program. When there

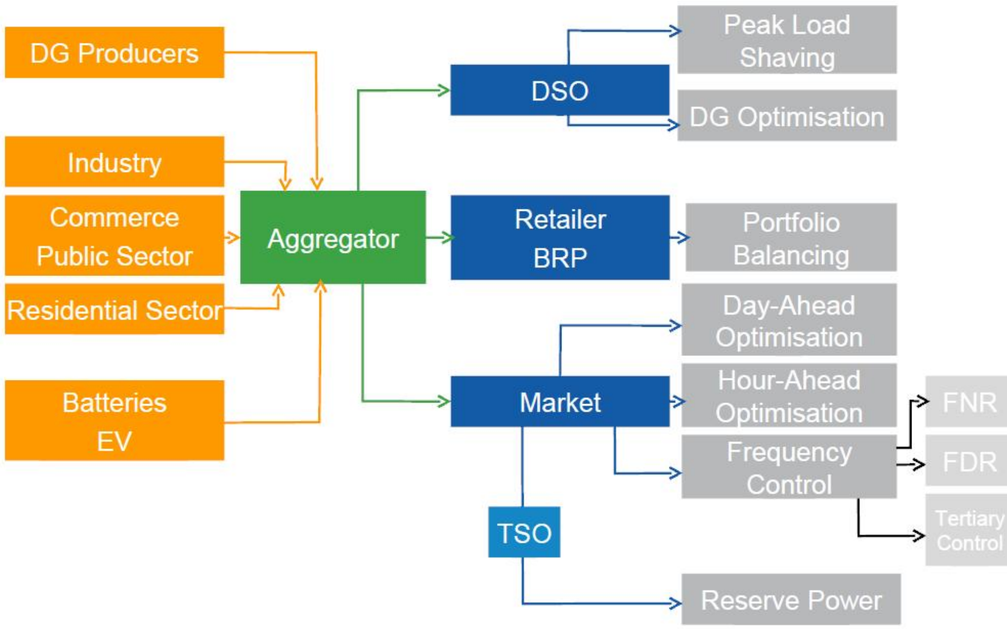

Figure 16: Synthesis of the Aggregator's Business Services, Clients and Providers. [14]

starts to be a critical mass of participants, where the price of electricity affects to the amount of demand the challenges occur. This flexibility affects to the Spot-price because the demand and supply meet in different equilibrium than without this flexibility.

Letting customers or aggregators enter bids for their demand gives them the opportunity to indicate the value of their load in a more transparent way. There is little experience of the subject with demand-side bids and therefore it is not clear how this affect the actual behaviour of the consumers. [13]

4.2.3 Energy Service Company (ESCO)

Energy-efficiency is one of the three pillars in EU's energy strategy. Cutting the emissions from the end-use of energy, the benefits increase exponentially when going back to the primary source. Energy saving potential still remain untapped, from historical reasons there hasn't been any pressure to optimise the energy-efficiency until recently. As the energy-efficiency have become more popular the companies which have in energy efficiency as their core business have emerged.

Energy Service Company (ESCO) is an interesting and important concept when looking to the future. ESCO is specifically energy-oriented commercial business that can help promoting the energy efficiency and offer its expertise in energy solutions such as energy savings projects, energy conversation and energy infrastructure outsourcing.

Satchwell et al. [39] defines the ESCO as

> ”A company that provides energy-efficiency-related and other value-added services and for which performance contracting is a core part of its energy-efficiency services business. In a performance contract, the ESCO guarantees energy and/or dollar savings for the project and ESCO compensation is therefore linked in some fashion to the performance of the project.”

The purpose of the ESCOs is to shift the focus from the unit of final energy (oil, gas, electricity) towards the purpose or benefit that the final energy unit actually produces and its optimisation (lowest cost of keeping the room warm, optimal air ventilation timetables). [23]

ESCOs help and provide the tools for the customers to manage and influence their energy consumption. The service portfolio can be quite vast, as it is seen in Figure 17.

Figure 17: Possible service portfolio of ESCO. [9]

5 Challenges and Possibilities

As any market has revolutionary transitions, roles and responsibilities of different players experience redesigning to fit the new environment. New players emerge and new roles are established. With proactive collaboration among participants, the markets can find the optimal solution under new set of rules. When establishing the roles, conflicts can occur among participants and some responsibilities are not so easy to categorize under certain actor. The change can be managed smoothly and without major frictions, but it is also possible that some of the new concepts, such as load control and energy storages, have a large interest from several actors. This might cause conflicting interests regarding them. Finding a solution that is satisfactory for all the players can be hard to achieve.

By the same token, vast changes do not necessarily change the roles too much and the threats for any actor can be trivial. Future's uncertainty creates doubts among players, but changes to environment usually brings unforeseen benefits for all of the players.

In this section the challenges and possibilities for different actors are discussed, as well as comments about changes of the market platform and the improvements are suggested. The discussion for this Chapter come from the interviews of experts in energy business, supported with literature studies.

5.1 Power Exchange

The traditional market platform faces challenges in a new environment. It has been designed from the needs of traditional energy business aspect, where the amount of energy produced were easier to predict, and products' time granulation was designed accordingly. EU's energy strategy has been one of the main drivers for the European market integration, a long process where the first steps have been taken. Creating an integrated PX, which takes into account the new requirements of the system platform and requires different PXs collaboration, is a long and difficult task.

5.1.1 Challenges

Potential loss of liquidity on the PXs
As there has been debates about the introduction of capacity markets to Europe, the impacts for PXs and financial commodities exchange encounter a threat. With larger proportion of fixed income, the incentive to hedge the electricity reduces. The role of the PX can be questioned if the development is facing strongly to the old, regulated markets direction. [71]

Difference in business objectives of PXs
Deciding the common goals for the PX is difficult, and one of the main reasons is that PXs have different interests and views on business objectives. Lundin [65] categorizes these as follows:

- PX as a state institution and steering regulated by law – Run more like a part of the government's administration
- PX owned by TSO:s – Balance between business and public service interests
- Business entities owned by market stakeholders – Focus on business and what's in the interest of the participants

The ownership of the PX defines largely the business objectives of the platform. As there is a variety of the different ownerships, it is seen problematic to start forming the common targets. With different behaviour and the focus among PXs, it is hard to find the solution that would be suitable for everyones' needs.

Competition among PXs
Derived from the previous point, as it is not possible to find the satisfying solution for everyone, different PXs are under competition situation where the strongest wins. Competition hinders the collaboration for striving to integration of the PXs.

Disagreement about common PX's structure
PX's have a variety of different kind of structures for day-ahead markets, intra-day markets as well as a variety of balancing mechanisms. The functionalities are not easy to integrate, as different mechanisms have different benefits and restrictions. PXs have biased view on what would be the optimal solution for the whole Europe.

First obstacle when discussing the coupling of the markets comes from designing of the new product portfolio. It is hard to integrate the products with different time periods that exist in different PXs now. Time resolutions for intra-day vary from 1 hour to 15 minutes, depending on PX.

15 minutes would be a radical shortening of the time resolution for the Nordic market perspective where both day-ahead and intra-day markets have had an hour granularity. Transmission system operator (TSO) has very accurate plans for consumption and production, and by shortening the time-window would require more resources on activating bids in Balancing market from TSOs point of view. A 15 minute period is radically short time period from actor's perspective as well. It leaves little time for actors to correct imbalances, resulting in full-time job to follow the changes in Balancing market. [29]

Creating a trading mechanism for whole Europe
According to Lundin [65], the core challenge for PXs is the creation of the integrated trading mechanism to whole of Europe. The calculation of the spot price and reference price, which covers all the areas and simultaneously takes into account the capacity on all cross border allocation in one batch. The challenge is not a technical: one price calculator for the Europe can be done technically. Problem is the lack of interest to strive consolidation of the business forward at fast pace.

5.1.2 Possibilities

Additions to product portfolio
The integration of the product portfolios requires work, but it has a possibility to create the most suitable products, losing the historical burden on the design of the tradition. By designing a well-structured and attractive product portfolio, it will attract more actors to the platform, and thus making the field more transparent and has a positive impact on PXs growth.

Benefits from European scale markets
PX has the possibility to find growth more easily if there is a pressure for the integration of the markets from the European Commission level. The expansion to larger market area helps the coordination and gives better insight about the bottlenecks in system, helping different TSOs' collaboration on building the international transmission lines.

5.2 Aggregator

Drivers for aggregator business vary from environment. In the USA it has been because of the bad infrastructure. Lately Germany started the "energy turnaround", the term which includes the increasing amount of renewable energy, replacing conventional energy sources and also phasing out nuclear power. [78]

For the Nordics, the pressure does not come from the infrastructure side nor political decisions concerning the energy generation structure. A main driver for the Nordics is in the market structure. In the Nordic market structure occasional price peaks cause the driver for demand flexibility. [92]

Positioning of an aggregator in electricity markets depends from the assumptions that verifies its existence. Two aspects are important to identify: which end-users have enough potential to form the needed mass to build a service, and who are the customers interested for buying the flexibility service.

As a new player, the role of an aggregator in the network is discussed in the next subsection. After that the main challenges and possibilities for an aggregator are introduced.

5.2.1 Establishing a place in Markets

Demand flexibility requires an aggregator to exploit its potential. The energy production has economies of scale, but demand response has different idiosyncrasies. It has to be built from small units in order to get the critical mass needed to make an impact. By collecting these resources the electricity markets get a new actor, which hasn't been there before.

A new actor in the closed environment can cause confusion among players. How to implement a new actor and its role in optimal way is under the debate. Existing roles of different players have established over time and certain actors are regulated with law (DSO, TSO), so an aggregator's position in this environment is not clear yet. [92]

A possibility to become a market actor
An aggregator does not necessarily have to participate in electricity markets. It can provide a service to the customer which optimizes the energy usage to be as cheap as possible. The problem follows from the fact that optimizing, i.e. changing the expected behaviour of a customer, has impacts on other players. By modifying the customers' load curves, an aggregator causes deviation to the consumption profiles. A retailer has to forecast the profile beforehand, and deviation means additional risks to the retailer. If an aggregator has this kind of business model, conflicts occur without communication between players. Functional communication is essential to make the business viable for an aggregator.

Other solution is where an aggregator provides the electricity to the customer, i.e. becomes a retailer. When becoming the market actor, communication need with a retailer disappears but now an aggregator is responsible for the balance sheet, which brings new risks and challenges. This business model has its restrictions, since retailer business is not the core competence nor focus for aggregator. Therefore, it sounds logical that collaboration can bring more benefits to both players.

Strategic decision about customer segment
In different markets there are different potential clients to be found. A size of an client can vary from large single industry player to small, single household with electrical heating, with very different preferences and expectations from the service. Market research is an essential task to do, to find the providers that can be flexible enough. Market research is a long and complicated task to do properly. To find processes that can be re-arranged more optimally will require deep understanding from customer's needs.

Strategic decision about choosing operating markets
Another strategic decision needed is the decision where an aggregator is operating. Demand Response can be offered to several different markets, depending on the nature of the flexibility possibilities in each load. Participation possibilities for different markets range from Spot-markets to fast disturbance reserves.

Selection depends mainly from the time-slot in which the load can be turned off without causing major disturbances to other processes, for instance the cooling systems in cold storages have boundaries concerning the maximum temperature allowed to keep food products fresh.

Another aspect when deciding the market is the reaction speed of the controlled load. Markets that are related to power shortages can happen fast. For Balancing markets the load reduction is required to be activated in 15 minutes' time.

Of course, an aggregator can choose several different markets to operate, but it requires effort and lots of automation to constantly update the highest value from different possible markets.

5.2.2 Challenges

Several challenges were discovered from the real-world implementations of aggregator. Based on interviews, the main problems are as follows.

Attracting clients

Attitudes of the clients whose loads could be controlled has proven to be mixed. Main reason is difficulty to estimate exact savings it would bring to a client. Savings volatility makes the pricing of the service difficult. Usually the loads are a part of the processes that are delayed because of the DR. If one cannot estimate the savings, comparison of a trade-off of this action cannot be done.

Clients also have popular misconception that the benefits are very small that it isn't worth executing. Argument for this can be based on arbitrage: if savings through better adjustment of electricity usage is risk-free, a rational actor should do it. [92]

For small-scale clients the challenges is that it is hard to reason the benefits because of the lack of knowledge about electricity markets. Initial investment for HEMS can be too high and payback times can prolong to several years, which reduces the attractiveness of the product. Also the development of the systems are rapid so one gets advantage to wait for a longer time. [86]

Communication with policy-makers

As the DR is such a new concept, getting regulation adapted to DR has been a challenge. From traditional perspective, where the problems with grid stability has been solved through big projects like building more transmission lines causes certain mind-set to politicians. This new, capital efficient technology is not easy to explain. Since it's not easy to comprehend, policy-makers don't understand to create incentives for it, which in turn means that ancillary services do not seem so attractive to actors under regulation. [78]

Existing player expands the business to aggregation

Existing actor in markets can begin to offer aggregation services, using the existing customer base as an advantage. Retailer companies have an excellent possibility to penetrate into aggregation: the business model doesn't differ from an aggregator who becomes a market actor.

5.2.3 Possibilities

Markets have a need for DR

Alongside with sufficient transmission capacity, price elastic demand is seen as of crucial importance when creating the functioning markets. [18] The Nordic markets is matured to the point that the next logical step for development is to thrive for demand flexibility. There is clearly a demand for this kind of actor who collects the flexibility from smaller fractions to larger units that can participate in markets.

The markets is in need for this kind of service, but the system side is interested as well. Demand flexibility can be exploited to problems from both sides: bringing savings from markets to customers as well as bringing relief to congestion problems that system will experience.

Shorter time resolution demands more automated systems
Inevitable shortening of the time granularity in markets makes aggregator even more valuable via direct, automated load control. Price of flexibility increases, and since the time window is so short, the inexperienced customers do not have resources to follow the markets' signal shifts fast enough. Through this scenario, it can be seen that in future the demand for dynamic tariff combined with direct load control gains interest. Absence of direct load control can lead to a situation which is unfair for the customer. [80]

When considering the situation in a larger scale, the markets should be still developed in such a way that flexibility both in demand and generation are still mainly in the day-ahead wholesale markets. The challenges from the DER makes the requirement hard. Thus, when forecasting accuracy weakens, it makes the job for Balancing Responsible Party even harder, opening possibilities for an intra-day aggregator at the same time. [73]

Prosumers need an aggregator for market participation
The customers with own production as well as possibility to have flexibility in consumption cannot participate in wholesale markets as such, since the amount of energy is too little. These prosumers need an actor which collects the resources together and bring them to the markets. A need for an aggregator grows as the small-scale generation becomes more and more popular.

5.3 Retailer

Retailer encounters challenges from the changing of the business environment in form of the increasing competition and strategy re-evaluations. With integration of ICT, a vast spectrum of possibilities what the retailer can do outside from the traditional focus. At present the core business is a risk management in the wholesale markets, in future the focus can turn to more customer-centric solutions, ranging from energy-efficiency to promoting the customer's own renewable energy production.

5.3.1 Challenges

AMM enables dynamic tariffs
In Finland, the Smart meters are installed which provide the data about the consumption every hour. This has a major impact on the retail markets. Meters enable the real-time, dynamic tariff. If the tariff becomes more popular, the pricing of the electricity becomes very straight-forward, leaving little possibilities to compete with margins. This gives pressure to the retailers to expand the business to other sectors, such as service-providers.[69]

Competition increases

ICT enables more active customer participation with better understanding on how the energy is consumed. There are different ways to increase the energy efficiency which brings new participants in the markets, such as companies specialised in Home Energy Management Systems (HEMS) and ESCOs.

Emergence of the new players mean that the competition from customers tightens. There will be new competitors outside from the traditional electricity retail sector. Trend is that retailers become more of a service providers, which help customers to save energy through collaboration. [80]

Retailers stretch out from their present core business, which is acquiring the electricity from wholesale market and selling it to customers.

Moving away from the comfort zone

Since the nature of the business evolves, the retailer has to update the strategy accordingly. If the scenario is not well known, choosing the right strategy results in profits and by choosing the wrong focus on strategy risks the whole business. Analysis of the future and innovativeness is of high value when deciding the winners out of the market change.

If the strategy change involves more emphasis on the creation of the services to the end-users, the retailer has to adapt new ways of working, without the previous experience. Seminal changes to strategy has to be evaluated carefully, and companies with a long history might be uncomfortable to update the procedures. Reluctance to undergo a transformation may result in losing the business to more agile companies.

5.3.2 Possibilities

Easier to differentiate from competitors

With more options in possible strategies create an advantage. It is easier to differentiate own business from other service providers, by creating services to the certain segment. By creating differentiation of products successfully, a retailer can achieve monopolistic nature in certain segment, where perfect substitutes for the service are hard to find.

Collaboration with other sectors

Retailers have a vast experience from electricity markets' behaviour. Collaboration with a company which has different core business can create advantages to both players, an alternative solution to expanding too much to new areas [73].

First steps in collaboration has been made recently. Fortum's collaboration with There corporation, which manufactures HEMS, Fortum has been able to create a new product, Fortum Fiksu. In this solution, There-corporation provides the hardware solutions for controlling the loads and Fortum provides the Spot-priced electricity contract. Through synergy a customer gets a service which decreases the electricity invoice by optimising the heating load usage. [38]

Benefits from collaboration can go much further. Creating new products and doing market research requires investments. Collaboration helps to share the R&D

costs, thus increasing the possibilities to research the projects that would have been too expensive for one player to carry out. [79]

Product portfolio increases

Creating services becomes easier by exploiting the data from AMM. Retailer is provided with more detailed data on customer's behaviour. The retailer is able to create more detailed picture of customers needs, which lead to a variety of different products and services. Larger product portfolio enables the business growth and provides larger customer base with more competitive products.

5.4 DSO

Changes in environment affects the DSO as well. Inflexibility in production side will make the stability of the grid more difficult to manage. The transition from passive, solving situations by grid investments approach towards more ICT-centric business has impacts for the regulated, neutral player as well.

5.4.1 Changes in the role

Because of the natural monopoly, DSO's business is regulated. Regulation causes restrictions and limits in its role. The revenues are fixed and the participation to the electricity markets is not possible.

DSO is seen as a neutral market facilitator, enabling the platform for the functional electricity markets. A Smart Grid have a lot of components that can be used in the open markets, like energy storages and DR, so the Smart Grid has to be seen more than just a technical infrastructure managed by the DSOs. General view is that the role of DSO should remain as a neutral actor after enabling a Smart Grid. DSO should be kept separate from open markets. DSO provides the platform for competitive players to offer new services. New services should be created by the market and the regulatory framework should support the market-oriented approach. [62]

However, in areas where there are already significant amount of renewable energy production, ideas for updating the DSOs role to more active approach has emerged. DER causes DSOs to reinforce the grid connections in order to secure the grid stability. Grid has to be designed according to the peak load, which might in some cases happen only a few times a year. If the peak hours do not happen very frequently, it would be beneficial to avoid the congestion situations by using the flexibility services rather than investing more to the grid.

It is discussed that if DSO has more options in managing the production or consumption of electricity, it could optimise the investments to the grid more efficiently. For instance, DSO could acquire DER services from the open markets. A new market platform would be created for aggregation services and price will form transparently, whether it is signal from markets or from the system level. Commercial players offer the services to TSOs and DSOs as pictured in Table 5. This concept is market driven and based on voluntariness, with benefit of creating new business potentials to energy environment. [61]

Table 5: Roles of different actors in flexibility service model. [61]

Actor	**Role**
TSO	Demander of flexibility services
DSOs	Demander of flexibility services
Commercial players (Retailers, aggregators etc.)	Supplier of flexibility services (Through aggregation of Consumer / DER resources)
Consumers / DERs	Supplier of flexibility services

Market platform for flexibility services has certain aspects that need to be considered and clarified before implementing. Possible challenges about the viability of the concept can be enlightened with following examples.

Players have unequal power position

If DSO rely on the flexibility markets and do not invest to the grid, it can result a situation where the supplier of flexibility services can put unnaturally high value to the service, since DSO has no choice but to buy it anyway in order to secure the distribution grid stability.

By the same token, DSO can also use power position and avoid participation for this kind of market model completely. It is stated by law that if security of supply is at stake, the DSO has a right to drop the loads in order to secure the stability. Thus, if DSO can affect to the flexibility itself, it reduces the need to use the flexibility markets.

Flexibility markets do not have desired effects to network planning

DSO is seen as a potential customer for this kind of service, as with the working flexibility markets the DSO can change the network planning to more intelligent direction, deferring the grid investments through load shifting.

A threat is that even though DSO has interest in flexibility services, the practices of long-term network planning may remain unchanged. The distribution grid is still planned according to "fit-and-forget" approach, meaning that it is fitted to take care of occurring peak power. The distribution network is planned for decades forward. The planning cannot trust too much for the demand flexibility. The voluntariness of the flexibility makes it even harder to build trust for grid planning.

Moreover, the model does not take into account the factors related to capacity requirements of the grid. The capacity built depends on a variety of factors: adequate capacity to handle the power peak is just one of them. The safety in fault occasions and special situations such as transformer failures have an effect to the grid planning as well. [96]

The reasons mentioned suggests that planning will be done with an assumption of no intelligence in the grid. Without exploiting the intelligence of Smart Grid concept the benefits are just marginal, if any. If planning tools do not develop, it continues to be business as usual.

A farrago of signals may result in unoptimised controls

The system becomes easily very complex when there are several signals from different sources. Signals can have opposite effects. The overall optimisation and the price-calculation in real-time can become obstacles.

For example, if the price forms in open markets, the DSO has calculated that at certain price range it is cheaper to use the flexibility service rather than strengthening the grid. TSO has made the same calculation and has its own price range. Electricity markets create a third price range for the parties offering the service. Problem arises if these three prices conflict, i.e. everyone has an exigent need for the service at the same time. Therefore the price may get so high that it is not profitable any more, but since the need for it is crucial the service has to be bought no matter the cost. Strengthening the grid would have been cheaper in the first place.

In order to make DSO believe that flexibility markets are relevant is to create a guarantee that DSO has the service available when needed. A privilege certificate to the service over others' signals can build trust to this concept. Otherwise there is a danger that the flexibility markets will never happen.

The implementation takes too long

There is a justified doubt for ancillary service markets' development pace. A fear is that at the time when these smart solutions will be available, they are not required anymore for generation management, because the grid is enhanced already.

Also the readiness of DSOs to penetrate to more active role is questionable. According to Tenschert [97], DSOs in Austria (which can be expanded to other countries where DSOs are already experiencing the effects of DER) are presently not ready to become active players on energy issues or even ancillary services. Austria has rather strong regulation system and therefore professional resources at DSOs in this respect are not available because of cost restrictions. In practice it seems more important to talk about the solutions of today and of tomorrow. It is too much discussed about the days after tomorrow. Of course we must think about after tomorrow, but before we have to solve today and tomorrow.

5.4.2 Challenges

Data management

The main challenge is the managing and distributing the data, which now has become a relevant part of the DSO's business through new regulation. In Finland the DSOs are responsible for acquiring, storing and delivering the data from Smart Meters to other market parties. It is a completely new function for the DSOs. After the acquiring the data, it has to be verified. The system built has to be very reliable, since the mistakes and flaws become very costly: retailers' and DSOs' billing rely on the data acquired. [85]

Tariff structuring
The present tariff structure for the DSO does not reflect the actual costs. It should be changed from energy-based structure to power-based. As a solution for this the "bandwidth"-tariff has been introduced, where the customers pay for the maximum capacity they use. This system has been criticized for not taking the energy-saving aspect into consideration, and also that if it would be introduced in a short transition time, the price differences in the electricity invoices would be too radical for some customers. [85]

It has also to be noted that if the signals come from both the markets and the system level, the signals can be conflicting. There can be a problem that customer can have mixed signals and does not understand what to do. This confusion can lead to unwanted behaviour, even though the idea was initially to have better overall optimisation for society.

Further in the future when micro-generation has a significant part in energy-mix, with more own production, there is a possibility that the grid is used more in a way of a "battery", and net energy consumption can become quite small. This is a risk for DSOs to lose their revenue if the tariffs take account only energy consumption. One solution how to get the tariffs closer to the equivalent of reality is to change them to power broadband tariffs. Then the strengthening investments are directed to the customers who actually demand it. [79], [19]

5.4.3 Possibilities

Better knowledge from the situation on the grid
Data collecting also means a lot of opportunities for the DSOs. By knowing the consumption more accurately and better knowledge on how the power flows move will give more detailed picture of the state of the grid. Knowledge helps DSOs to develop their own processes more effectively. The real-time state helps to ease the stress on bottle-necks. In addition, data brings long-term benefits as well: better and more accurate tools for the long-term planning can be created.

DSO as Market Facilitator
How the ICT infrastructures are integrated to the energy sector are currently under debate. A common infrastructure for the information distribution, a data hub, which all the players use can lead to a conclusion that the facilitation should be done by a regulated entity, to avoid the misuse of the system.

It has been presented that DSO would function as a facilitator of this information exchange. As a regulated entity DSOs would be able to act neutrally towards market actors, securing functional platform where players operate in open competition. In Figure 18 the overview of the model is presented.

Benefits from this would be that the platform would be facilitated still with regulated entity, and at least in Finland it would be logical to keep the metering activities as an DSOs responsibility since the roll-out of the smart meters and the metering systems were done and chosen by DSOs. Also the roles for the other players would remain more or less the same. The customer would participate in the

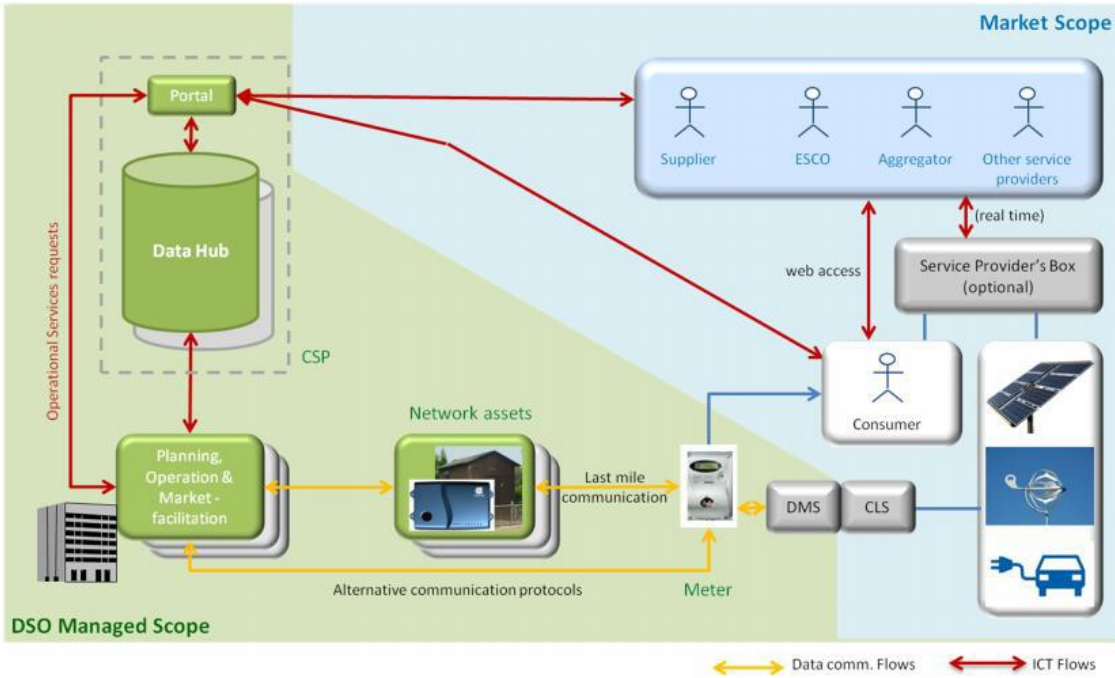

Figure 18: 'DSO as Market Facilitator' Market Model - High-level overview. [10]

electricity domain through commercial contracts and the retailers would be able to focus on developing new services to the customers.

5.5 TSO

5.5.1 Challenges

Lobbying for the Nordic Market Model in Europe

On market perspective, the largest challenge for Fingrid is the ongoing European Market integration. Although the European Commission's target model for the market integration is similar to Nordic market model, it has caused a lot of resistance in European level, as it would require vast changes to existing market models. There should be more drive to target model direction. [77]

Exploding reserve costs

The increasing amount of DER makes the system more volatile, especially in the transition state where the electricity system has not adapted to the rapidly increasing growth of intermittent wind power. A research [60] illustrates the scenario where the price impacts from the wind power increase are unnaturally large because there hasn't been enough proactive investments to the Balancing power. Strong increase in intermittent renewable production, combined with phasing out of the old capacity may lead to a situation, where the existing Nordic Balancing system is not able to cover the possible fierce disturbances the system experiences.

Communication Gateway with DSO

One segment that is important for TSOs in the future is to establish a working communication gateway in Customer – DSO – TSO chain. There hasn't been need for this in the past but now there starts to be a pressure to communicate more intensively. More collaboration among these stakeholders is needed in order to communicate the signals on what is the state of the grid. [77]

5.5.2 Possibilities

More intelligent solutions are available instead of building reserve

Increasing flexibility in demand-side becomes of great use for the TSO. Adding capacity cause monumental investments from TSO. In cases where the peak power is used only a short time in a year, it would cause vast savings for TSO if these few congestions could be handled through DR instead of building more capacity. DR is a cost-efficient way of solving the reserve investments. Also energy storages are explored to ease the problem. [86]

More variety in product portfolio

Variety of products can be designed, when new kind of production and flexibility is brought to markets. It provides help to more specific kind of situations that TSOs might encounter. Collaboration with an aggregator in service design can create realisable service structures.

5.6 Generator

5.6.1 Challenges

DER subsidies distort the markets from optimal equilibrium

A generator sees the diminishing of the overall markets when DER starts to become more popular. If the end-users produce the electricity themselves, the amount of electricity bought from the wholesale markets starts to decrease.

The structure of electricity generation experiences negative impacts from DER since the marginal costs of renewable energy are practically zero, if the renewable energy is subsidized for example through feed-in tariffs. It leads to a situation where it is always profitable to produce electricity, even when there is already excess amount of electricity in the markets. In Figure 19 the graph of supply structure is shown.

When there is a sunny and windy day, it pushes the whole supply curve to the right. This becomes challenging if the system starts to have a significant amount of renewable energy generation. In case where the DER generator is not exposed to real market price, the supply might increase so much that it forces normal base load power plants to ramp down the production.

Either the renewable production should be constrained or the base load plant's production. Logically it should be DER since with renewable energy power plants the control is easier, when as nuclear plant's response takes more time. The peaks from wind or solar can escalate quickly, within an hour or even less which can be

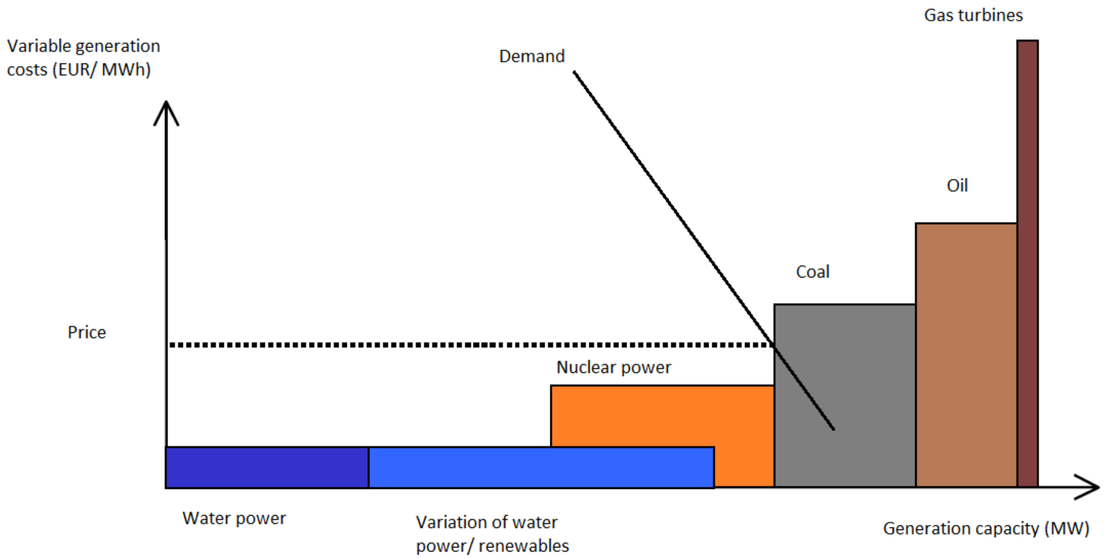

Figure 19: Renewable generation effects. Increase of the renewable energy pushes the supply curve to the right.

too short time for base load power plants to react. Therefore DER should have the same incentive than others to adapt to market needs.

DER lowers the price of electricity in the wholesale markets
The Figure 20 shows the effect of DR and DG on the price formation in wholesale markets. If the price difference is significant between hours, the flexibility of demand shifts the consumption to cheaper hour, thus pushing demand curve more to the left. Alongside with added DG, more production pushes the supply curve to the right. These factors together push the price down, inflicting less revenue on generators.

5.6.2 Possibilities

Value of flexibility increases
The closer we get to the delivery hour, the less there is generation or load to be able to react fast enough. If forecast accuracy weakens, it is not necessarily a negative aspect for all generators.

Forecast weakening causes the value of flexibility to become even higher in future. If the generator has a lot of easily controlled generation such as hydropower, the fluctuation that DER introduces can be beneficial for the generator.

5.7 Customer

5.7.1 Challenges

Anxiety towards more accurate monitoring
From the market research [11] it was noted that people might experience the increase

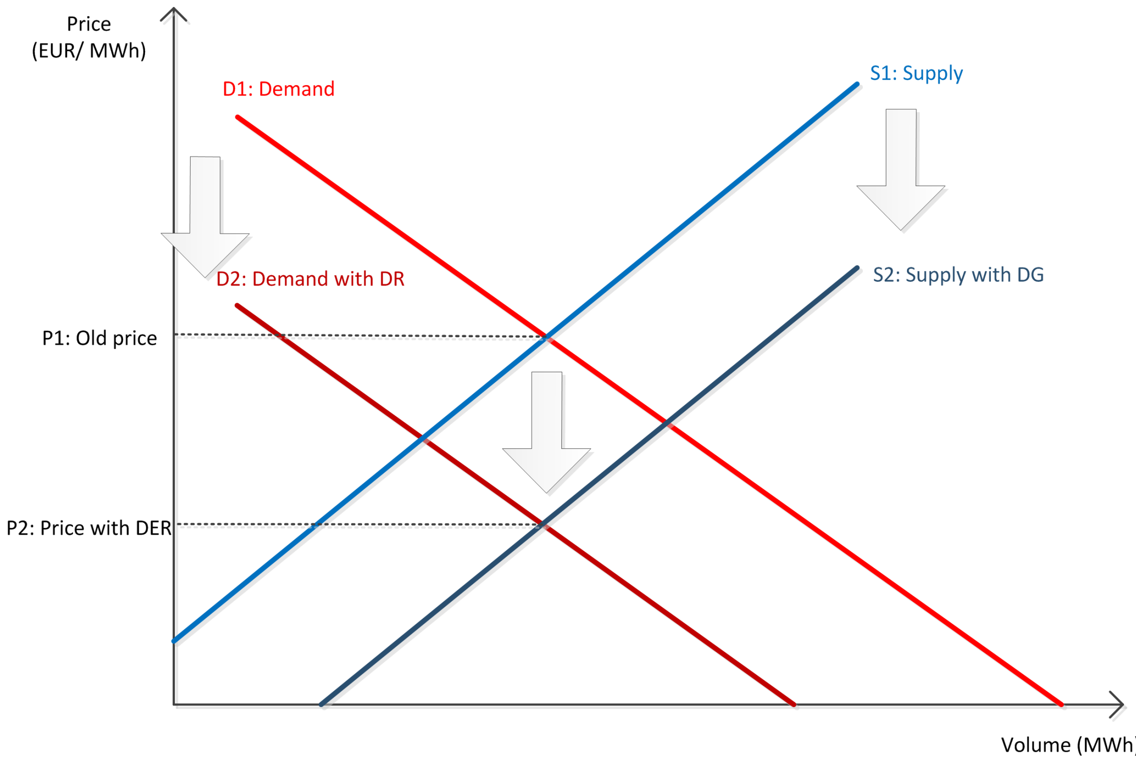

Figure 20: Effects of different techniques on price formation.

of monitoring as going to "Big Brother watches you"-world. Many feel that in modern society there is a lot of surveillance even in places that are not necessary needed. It increases anxiety and adds more neurotic aspects to everyday life.

5.7.2 Possibilities

With more accurate data collecting, the customers will get new service offerings from the retailers as well as the quality of services gets better, more focused, custom-made services.

Monetary savings

It has been estimated that more detailed knowledge about the household consumption, for instance by using the in-home displays, would bring up to 10 % annual savings. [2]

With a smart meter it is possible to follow and adjust one's energy usage, since the data is based on real consumption rather than estimation of it. In future, the customers are able to follow their electricity consumption in real time. In 2011 Fortum started an in-house display-pilot, where households could follow their electricity consumption in real-time. The separate device was installed to 180 households. The customers' reviews were positive, although it was seen that more functionalities, such as device-specific measurements were needed in order to understand the electricity consumption in more detail. [11]

Better products available
With ICT, it is possible to get more detailed data about the customer behaviour. A retailer can use this data in order to do more focused, customised solutions for different customer segments which take into account the exact wants and needs for each customer type. [91]

5.8 Summary

When finding new roles for the actors in the field, more holistic perspective is needed. Dialogue among players is important when it comes to finding an optimal solution, meaning that resources are used as efficiently as possible from the society's point of view.

Every player undergoes challenges as well as experiences opportunities. In Table 6 the main opportunities and challenges are summarised for each actor.

Table 6: A main opportunity and a challenge for every shareholder.

Player	**Challenge**	**Opportunity**
PX	Competition among PXs hinders the common platform development	Possibility to vast expansion of the platform
Aggregator	Difficulty to introduce new concept in large scale	A need for demand flexibility
Retailer	More competition in sector from ICT-companies	Possibility to expand the product portfolio
DSO	Handling the data management	Better tools and knowledge from the grid through more accurate data
TSO	Exponentially growing reserve investments	More intelligent solutions are available
Generator	DER reduces marginal profits	Flexible production can become more valuable
Customer	Anxiety towards more accurate monitoring	Monetary savings & more customised products

6 Potential Conflicts of Interests

In this section the potential conflicts among players are reviewed. Many of them appear from the reasons that were discussed in the previous chapter: from challenges that stakeholders experience. Also an aggregator and a retailer overlap in certain conflicts. This is because of the similarities: if an aggregator operates in wholesale and in retail markets it has no difference whatsoever compared to the role of the retailer.

Results have been acquired through interviews with industry experts, and evolved ideas further for possible additional solutions to overcome the potential conflict situation.

Potential conflicts are structured as follows. First, the short definition about the conflict is introduced, which is followed with more detailed description of the problem. Last, possible evasive action around it is proposed.

6.1 Customer – DSO

6.1.1 DSOs quality of service may be compromised

The increase of DER lead to increased volatility in voltage levels and in worst case can result in blackouts if the DSO cannot manage the local grid constraints accordingly. Standard EN-50160 mandates the DSO to be responsible of securing electricity availability to customer when needed. Due to the costs of grid expansions, quality of service DSO offers may be compromised.

Discussion Standard EN-50160 defines the voltage parameters of electrical energy in public distribution systems. It sets the quantitative values that service quality must deliver, by making the evaluation of the power quality possible.

The requirements become more expensive to fulfil with intermittent DER. Network reinforcements to integrate the new DG units are necessary, causing more costs to the DSO.

If the generation location starts to move to the areas where there hasn't been generation before, conflicts may arise. The cable capacities is fitted to respond to the old situation. Cables might not be able to adjust to the new power flows. DSO has to re-evaluate its grid, since the situation can be that local congestions occur when the local production is over the local consumption.

Also the variations in voltage increases, causing harm to customer's devices.

Proposed Solutions As a regulated entity, the DSO has to provide certain quality level of service. Strengthening the grid is the traditional way to answer to the problem but it is only the result of strategic planning of the grid, thus applicable as a long-term solution.

With development in technology, DSO can widen the view to handle the challenge with new solutions: by using the SG components in order to use the grid more intelligently. For instance, DSO can invest to energy storages which have the capability to shave the peak and move it to a more reasonable time. Depending on business models, removing the bottlenecks with energy storages or through DR can be acquired from an actor from deregulated markets.

Solving the situation with a help of DER causes more potential conflicts. This is discussed in more detail in Chapter 5.4.1.

This conflict is only valid when there is a significant amount of DER integrated and the grid experiences congestions. In Nordics, the issue is not urgent: the grid has built to cope with vast differences in terms of capacity. This comes from history: the power levels fluctuate vastly because of the electrical heating that is used in winter-time.

6.1.2 Cyber attacks expose the system to vulnerabilities

Smart Grid environment requires ICT systems, applications, Internet and different data exchange services. Adding ICT exposes the systems to cyber attacks.

Discussion As the crucial parts of the energy system is controllable through communication networks, vulnerabilities can be manipulated to even dangerous proportions. For instance it can be possible to shut down power from large areas, causing severe damage to every stakeholder.

Experts [58] commented that cyber security hasn't been taken enough into consideration in Smart Grid pilots. Reason for this is that until recently, cyber security hasn't been a major part of the design phase. Primary concepts of the Smart Grid, e.g. business models and functionalities need to be addressed and goals clarified prior more detailed concentration towards cyber security.

Moreover, the attack area expands via HEMS and DR-systems to customer's premises when these are implemented as a part of a Smart Grid. Usually these solutions are internet-based. Actions of the devices on customers' premises are in the hands of a customer and customer's behaviour in the internet. Without safety control possibility, this is regarded as highly risky part of the chain. [58]

Proposed Solutions More weight to the cyber security already in design phase helps it to become more concrete part of the system. By doing this already at early stage will save time and effort, and results in maximising security. The complexity of the system increases all of the time and all aspects regarding safety is hard to take into account afterwards. [58]

European Network and Information Security Agency (ENISA) has constituted a group to identify and research the issue of cyber security concerning the Smart Grid. For more details, report can be found [58].

6.1.3 Guaranteeing privacy of consumers

AMM gathers detailed data from customers' behaviour. Ownership over the data, who can access it, and benefit from it is not clear for the customer. Having control over data sets a lot of responsibilities for the DSO. Customers' privacy has to be ensured in every step it encounters in a value chain.

Discussion In Finland, the DSOs are obligated to measure and distribute Automatic Meter Reading (AMR) data to retailer for billing and to BRP for imbalance settlement purposes. From 2014, DSO is also required to deliver data to customer at the same time as it is delivered to BRP and retailer. The DSO alone is responsible for the accuracy of the data.

The ownership of the data is not defined explicitly. Thus, it is compared to personal data, meaning that DSOs are not allowed to submit the data to any other purpose than for billing and imbalance settlement without customers' permission. [95]

With AMM, the customer's electricity usage is monitored more in detail. This can be seen as a problem since it gives a rather detailed picture on persons' or families' living habits. As the world evolves to more digital, customers start to get interested on what is done with the data that is collected from them. In research [11] it has been noted that many customers are scared about the loss of privacy.

In future energy domain, companies that create services to customers are getting more interconnected and dependent. Call for ensuring the data privacy throughout the whole value chain exists. Through standardized architecture of the Smart Grid communication interface can lead to successful result. [58]

Proposed Solution Customer acceptance is seen as a key success factor for enabling the Smart Grid. Therefore, privacy can be seen as even a more important aspect than a network security. Transparent and clear communication towards customer is needed to avoid this conflict. The restrictions and anonymity level of the data gathered has to be explained to the customer very thoroughly. For customers searching information regarding this issue has to be made easy.

6.1.4 DSO's tariff does not reflect real costs

Today's network tariff is an energy-based tariff structure including a fixed fee. This does not have enough cost correlation from DSOs point of view. Also customers suffer due to the fact that everyone does not pay according to the expenses they generate: an old tariff makes discrimination possible.

Discussion Tariffs are the only source of revenue for DSOs. The situation is peculiar now since over 50% of DSO's cost structure is comprised of building sufficient capacity, but the tariffs have fixed cost and the variable cost on depending energy usage, not power usage. [19]

Problem is that energy doesn't reflect the actual costs DSOs are facing. In future the gap between price structure and investments grows even further. This is due to the changes on how the grid is used. More microgeneration implies that the grid is used more in a "battery-like"-way, i.e. taking electricity from there when own consumption is not enough and feeding electricity to the grid if there's excess amount of it. This results that less energy is moved. If the tariff is energy-based, DSOs lose their revenue stream which is needed to cover the costs of maintaining the grid.

Another problem regarding issue is that customers experience discrimination. An illustrative example of discrimination is presented in Figures 21 and 22, where consumption of two customers are examined. Distribution tariff for both are the same, based on 3 * 25 A main fuse. As the costs for DSOs are dependent on peak power, Customer 2 causes higher costs for DSO since its peak power is a lot higher compared to Customer 1. Nevertheless, as the tariff is based on energy consumption and not the power component, due to higher energy consumption Customer 1 pays more. [19]

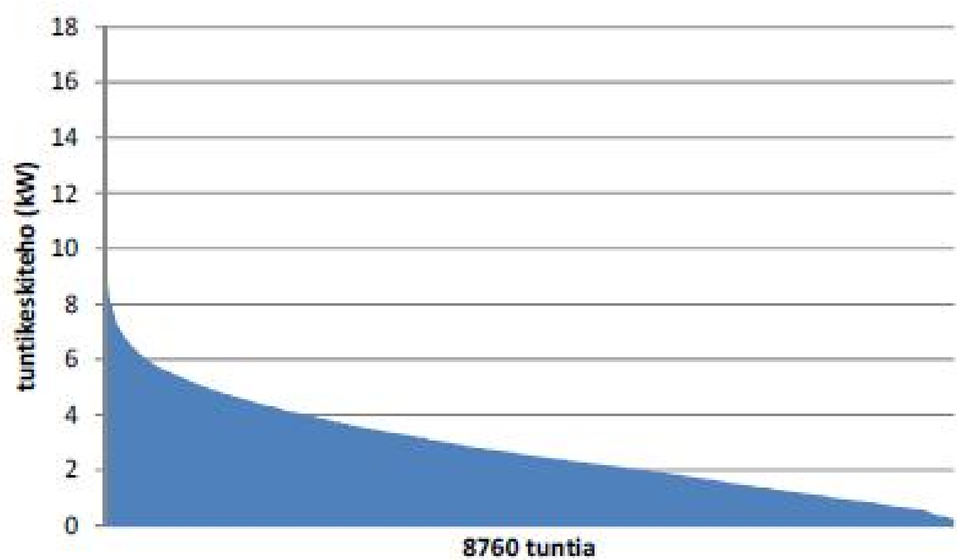

Figure 21: Customer 1: Yearly energy consumption: 24,9 MWh, peak power 12,4 kW. [19]

Proposed Solutions Different distribution tariffs are researched and studied to tackle this issue. "Power bandwidth tariff" is one potential tariff which has been proposed to solve the unfair situation. It is thought to be relatively simple for customers to comprehend since analogy can be drawn from the telecommunications business. Customers have an idea of this concept through their broadband internet contracts: the price depends on how much customer needs bandwidth. Essentially it is the same as the fuse size customers have now, but with more dense intervals in power scale. [79]

For DSOs, the bandwidth tariff would bring cost correlation: customers pay the correct price for their behaviour.

Even though bandwidth tariff would delete discriminations between customers, it has not been implemented yet. Customer's understanding may not be in such a

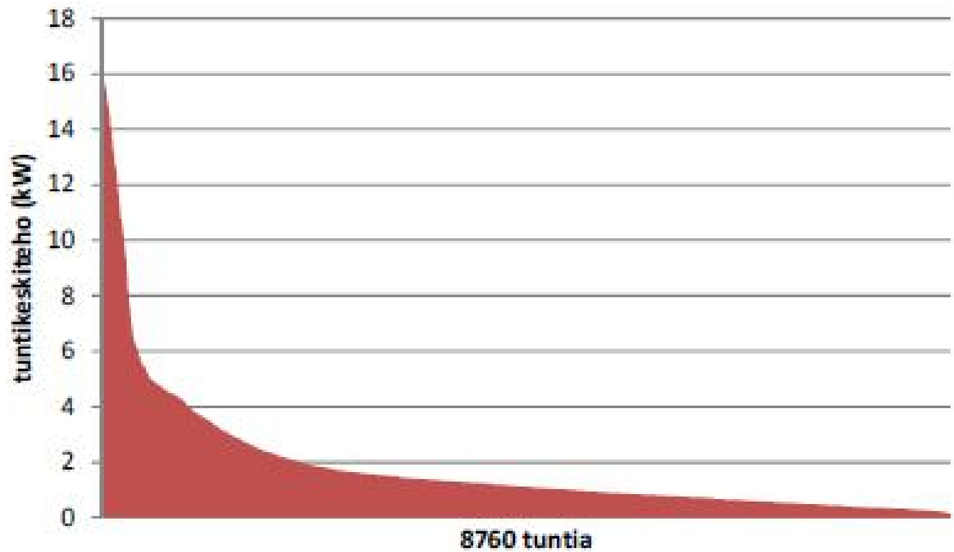

Figure 22: Customer 2: Yearly consumption 16,1 MWh, peak power 16,7 kW. [19]

good level as assumed. It is proposed that a new model is too radical compared to the old tariff which causes confusion among customers. Implementation should be done gradually so customers have time to adjust to the changes. [95]

Unease concerning the energy-efficiency is another potential threat. Now when both tariffs, transmission as well as electricity consumption are both energy-based, customer can realize on how one can save energy and therefore get financial benefit. Bandwidth tariff is seen as a potentially threat to energy-efficiency schemes. [85]

This reasoning does not take into account that with bandwidth tariff customer can make an impact to the size of ones distribution fee. As transmission fee is close to half to the total sum, this can bring financial incentives for customer to start being more energy-efficient.

More detailed studies about network tariffs can be found [2], [19].

6.1.5 DSO carries the risk for insolvent customer

In Norway, the DSO has the responsibility to sell electricity to a customer if one cannot find a retailer from the open markets. A risk from potential customer's insolvency is carried by DSO. [52]

Discussion When designing the billing system the focus turns easily to question of risk management. Today in Norway, DSOs have an interesting role since it acts as a supplier of last resort, meaning that it is required to deliver electricity to customer even if the customer is unable to get a contract with the retailer from markets. This can lead to a troublesome situation. If the customer is unable to meet its liabilities the DSO is financially responsible from the situation. The risk of this kind of insolvent customer is carried completely by DSO, whereas customer has no consequences for actions regarding the matter.

In a bigger picture when designing the future is to look at the mechanism of how the monetary transactions are done accordingly, where the right stakeholders carry the right risks.

If an actor is insolvent the sanctions should be dropped on the actor which causes the situation. Now it has been landed to the DSO without any compensation.

Proposed Solutions One way to solve this could be by paying the collaterals. This solution has drawbacks as well. With collaterals the market entry for the new, innovative start-up companies is made rather difficult. This isn't either the way on how we want the progression of the energy business to be heading. Still, more investigation on finding the healthy and sound solution to this incomplete situation is needed.

Another proposition is to transfer the distribution invoices to retailer, who then does the invoicing from customer. [85]

6.2 Customer – Retailer

Following issues regarding the relationship with customer and retailer were identified as a possible issues that needs solving or clarifying of the roles.

6.2.1 Vendor lock-in can reduce competition in markets

With increasing versatility of services provided, many of new services have a nature to be longer-term investments (e.g. solar panels, home automation). Lock-in through service contracts restricts customer's options in open markets, thus reducing competition.

Discussion Retailer can offer a variety of different services in the future. More detailed data from AMM expands the possibilities in product portfolio multi-fold, ranging from home automation to installing solar panels, possibilities are infinite. Basic energy contracts have smaller portion in the portfolio.

New technology solutions and devices are expensive with years of payback times. Contracts are adjusted accordingly, with longer commitments to the projects. Offering has to be done in this way for the products to be attractive.

It depends on how this is done. There can be a challenge considering the payback times of these new products, that the contract prolongs from what the customer have used to. This lock-in with the certain retailer can be seen as a challenge compared to the situation nowadays. For instance, these long-term contracts have changed telecommunications company and cell phone business' nature. With more strict and long-term contracts, the innovative start-ups have an extra barrier in order to penetrate to the market. Customers can suffer from this, as competition diminishes and large players have more strong dominance over the market.

On the other hand, longer contracts, when done properly, help customer to save money and learn about their energy efficiency. It is heuristic, long process that suffers if many parties participate in it. The learning curve of the customer is easier to evaluate when there is a longer relationship. Long-term contracts may also help start-ups as well. If a start up manages to get long-term contracts, it will result to more steady revenue flow, thus helping to build longer-term strategy to company. [91]

This feature emphasizes in the future when the characteristics of customers are better known and therefore the custom-made solutions become more popular and widely used. From today's world the analogy could be subcontractors where using the same contractor brings benefits since these are longer projects where value is realized in long-term.

Proposed Solutions Consumer protection policies supervises customer's interests. This secures that the contracts and terms stay in reasonable levels. The contracts have to be made clear to both participants to avoid problems with interests. When agreeing to the fixed time period contract, a customer takes a conscious risk and gets benefits in return.

6.2.2 Dynamic tariff transfer the risk to the customer

Dynamic tariffs, like Spot-priced tariffs will become more popular in the future. [91], [88], [74] A Spot-priced tariff will transfer the risk of the market volatility to the customer. Customer does not have enough resources to take the advantage from Spot-tariff, and unpleasant surprises in electricity invoices might emerge.

Discussion As many of the conflicts with customer on the other side, this case originates from the fact that customer does not have competence to follow the electricity consumption too closely. Customers lack time and desire to follow prices very accurately. This fact implies that there is little a customer can do to prepare for the sudden and large changes in Spot prices.

It is not easy to explain the vast variation of electricity prices to the customers. It takes a part of the risk of forecasting from retailer and brings it to customer. This can be a conflict, but also a possibility for the customer since now one really can impact the cost using the real market signal. [91]

On the other hand, this service can be used to enable more services behind it. Then retailer can provide additional service to do the demand response on behalf of the customer. Overall benefit margin to customer from this might become thin.

Proposed Solutions What is crucial on the subject is on how the dynamic tariffs are designed. The trade-off risk from constant priced tariff with premium against Spot-priced tariff has to deliver more value to the customer. Otherwise transition does not happen. Communication and clear information about benefits and the risks has to be explained to the customer in order to avoid unpleasant conflict situations. People like safety, so the question is how much extra value the alternative dynamic tariff can deliver. Other incentives, such as environmental values, have to be taken into account as well. Retailers have to do very extensive market research to find a right marketing strategy.

Of course, customers can always choose the flat-rate tariffs in future as well, but the benefits from changing the energy usage are smaller.

6.2.3 Retailer carries the risk of insolvent customer

In Finland and Sweden the local retailers, i.e. the retailer who has the biggest market share in the distribution network area in question, has the obligation to function as a supplier of the last resort. [52]

A risk from potential customer's insolvency is carried by the local retailer. Same discussion and solution is applicable as in the case of DSO carrying the risk in 6.1.5.

6.3 Customer – Aggregator

In this section potential conflicts between customer and an aggregator are discussed.

6.3.1 Trade-off between convenience and benefits from DR may not be sufficient

There is a trade-off between convenience and the benefits from shifting the loads to another time. Shifting loads have alternative costs, and the benefit from this should be enough to be worth doing.

Discussion In Nordics the small-scale aggregation has some prerequisites to make business cases more viable. This comes from the fact that there are a lot of electrical heating installed in houses. Estimations of it has been measured to be close to 1200 MW: exploiting even a fraction can make a significant business. [24]

So far small-scale aggregation hasn't existed. In the past technical barriers have been on the way of exploiting this in large scale as the payback times of HEMS systems have been too long. This is connected also to the price level of the electricity, which has been low historically. Controlling loads have not been beneficial enough. Now the transition phase is on its way: technology has advanced and economies of scale has dropped the prices of devices to a reasonable level. Energy consumption measurements have turned to more accurate and in real-time. Also developments in markets support demand response: dynamic tariffs are offered which enable the benefits from load shifting to customers.

With certain conditions, a small-scale aggregation is rational thing to do. For heating, it is easy to arrange without any harm done to the customer's comfort level. Situation changes drastically if aggregation is expanded to so called "white goods", i.e. appliances with large power in household level, stoves, washing machines, refrigerators.

General view is that going so deep to customer's everyday life is not possible. [78], [73], [81] The comfort level suffers too much compared to the savings achieved with behaviour manipulation. ”In Germany political pressure is on this kind of things at the moment. We see this kind of action waste of taxpayers time and money. It will never happen.” [78]

For larger customers it is easier to see the impact since the loads are much bigger and also convenience factors are not so relevant. Trade-off is done between saved money and causing fluctuations to process, either delaying or boosting certain part of the process.

Compared to a small-scale aggregation, discussing bigger-scale aggregation has better situation business-wise, but a similar problem lies here as well. Through doing field work to acquire the control over processes, two comments come usually from customers:

1. People see that it is not worth to control the devices, since the saving is so small. A counter argument for this is that it would be beneficial to still take that sum, since implementing the devices is not very costly.

2. It is hard to show quantitatively how much benefit one could get exactly, since the market prices vary year by year. Therefore selling of this kind of product can be tricky. [92]

Benefits from the DR should go to the customer. When reducing the load at certain time, it means that something is not done, a part of the process experiences delay for instance. This action has an alternative cost. In order to get this flexibility to the markets, the benefit has to go to the player who is willing to change its behaviour, a customer. [92]

The division of revenue between an aggregator and a customer might diminish the benefit to so small that it might be hard to convince customers to start collaborating with an aggregator.

Proposed Solutions Business cases for aggregation are viable, both in large scale and small-scale. Active role in promoting the idea for customer is solution for aggregation to take on hold. It is still seen as a new thing and the practices regarding the implementation have not been established yet. When aggregation becomes more popular it has potential to grow at a fast pace. [90] Also all the benefits from DR are not easy to see before doing pilots. ”In one of our pilots, the optimised load controlling resulted in more pleasant working environment. Compressor was controlled according to cheapest price hours, which are usually off-working hours. Now the noise disappeared during daytime. Employees were much more satisfied to the situation. One cannot find these benefits by doing only monetary calculations, but going out there and implementing the plan.” [92]

As customer gets enough understanding on what is behind the business logic as well as can negotiate a fair contract, the possibility of this conflict reduces.

6.3.2 Suspicion against giving away controlling possibility

Customers can get anxious about giving the control away from them. When bringing a new concept to the service business, the most important issue is to put together an aggregators' communication strategy.

Discussion It is hard to establish trust between a customer and an aggregator. People are suspicious to give the control away from their own hands, and the trust has to be earned. Also all the new ideas need assuring people how it really works, showing benefits clearly and how they are formed. The main point is that service should be effortless for them and the service delivers exactly what it promises. The service has to be very reliable from the very beginning. It was found that frustration can become too high if the service has reliability issues. It is crucial even in beta-phase to make sure the service does not experience too much uncertainties. [11]

Proposed Solutions For solution to ease the suspicion is two-fold: educating the customer and designing a well-functioning, simple to use product. The service offered has to be well-structured and designed to be as reliable as possible because in future, customers need simple, functional overall solutions. They do not have time for solving the details. This service has to be offered to them as a package. [91] This means that the service portfolio has to be made comprehensible for a person who is not familiar with the energy markets. One option is the overriding possibility to DR actions. It would ease the barrier for adapting the new systems.

6.3.3 Compensation for sold electricity is not sufficient in customer's perspective

The trend for microgeneration popularity is rising. Amount of microgeneration can exceed consumption at certain times. In this situation, the excess capacity is sold to the markets. If the renewable energy is not subsidised, the prosumer gets the market price for its produced electricity. Customer might expect the price of electricity to be close to what he is used to pay to the retailer, which is not true after taxes and transmission fees.

Discussion As the aggregation starts to develop VPPs, it might be that conflict emerges when prosumers see the fee of at what price is the aggregator willing to pay for the electricity. In a situation when there is good conditions for renewable energy production, it means that other microgenerators experience similar conditions as well. This generated overcapacity affects the system price by bringing it down. Without feed-in-tariffs, a single producer experiences this collapsed price. Selling excess production to the markets seems unattractive. [87]

The situation depends on what are the expectations of a customer for the produced electricity. Fixed tariff prices are the ones that customer has accustomed to. Customer might expect to get the same price for the electricity he produces himself, which is not likely to happen. The tariff prices include the risk of the price volatility that a retailer carries, taxes and transmission fees which means that customer might not be pleased to the actual price.

Proposed Solutions More clear understanding on how the price of electricity is formed would solve the problem. Teaching customers helps this process. Teaching is the best solution, but it is a challenge to actually conduct it. Best solution would be the clear communication on the realistic expectations of what will be the possible compensation sum before making the contract.

6.3.4 Generation resources' ownership

The ownership of the generation can have a variety of forms. Contracts and the allocation of the risks and benefits can cause friction between players.

Discussion When starting to plan on purchasing the micro-generation device, it is a question on how it is beneficial to arrange its costs. Ownership can be completely customers', it can be leased from retailer or ownership can be co-owned with another party. Prosumer starts to ponder the questions considering of the device's ownership and usage: who will get the benefit of the device.

Proposed Solutions Depending on the nature of customer and the size of the micro-generation plant, different solutions exist. This requires new approaches to the matter. New business models have developed for this issue. For instance in Denmark and Germany, public resistance against building wind turbines have reduced significantly when the ownership structure is such that it takes into account the local people, e.g. community-owned power plants or co-ownership of the utility with energy companies. [44]

New ownership models have worked for larger-scale wind turbine projects. The strategy might be possible to pass on to concern micro-generation as well, thus lowering the threshold for small customers to acquire a production unit.

6.4 DSO – Retailer

6.4.1 Different signals for load controlling

If DR is available through customer's load controlling, the control signal from market-side can be conflicting from the system-side.

Discussion Through AMR or HEMS it is possible for both actors to control customer's loads, but there can be the essential differences of the interests between DSO and retailer. DSO is responsible for keeping the system in balance within allowed limits, whereas the retailer wants to maximize the profit between sold energy and acquired energy from the wholesale markets. This can lead to problems since the lowest Spot-market prices does not always coincide with local network's power levels, creating unnatural power peaks and other unwanted features from the DSO perspective. [46]

Proposed Solutions By creating the market mechanism which would take into account the signals both from market-side as well as from system-side, the signal which needs the load reduction more will go through. In Section 5.4.1 the challenges with the market mechanism itself is discussed.

Also the signals might not be radically different always so the potential threat of this conflict can stay in small scale. In Chapter 7, the scale of this conflict, i.e. how much discrepancy in signals there has been historically in Finland, is examined.

6.4.2 DSO carries the risk from insolvent retailer

Risk allocation is unequal between DSO and retailer, from the same reasons as in DSO and customer, see section 6.1.5.

6.4.3 DSO may lose the customer interface to retailer

Supplier-Centric Model has been discussed in politics considering the future developments of the markets. In Supplier-Centric Model, the customer interface would be transferred completely to the retailer: customer service and invoicing would be done only with retailer. A suggestion has stirred a debate among DSOs. For some DSOs, losing the customer interface is seen as a threat: a customer cannot get local, expert knowledge to problems regarding the grid. [64]

Discussion Regulation is leaning strongly towards Supplier-Centric Model. SCM is thought to be most customer-centric approach available: Customer has to contact only one party, has only one legal contract and receives only one invoice. [49] Criticism regarding the model argues that benefits from the system are not enough compared to investments made: SCM requires very large-scale, reliable data systems with vast amounts of data transferring by DSO. In Figure 23 basic structures of the two competitive market models are demonstrated.

DSO would not have connection to the customer but has a crucial part in enabling the data from the AMR to the different parties involved.

Proposed Solutions For the solution it has been proposed to build a common data hub for all the stakeholders to use. Standardization of systems would divide the expenses of the project to the larger group, and through collaboration with larger DSOs, also smaller DSOs would benefit from this. Building a common large-scale data system requires strong guidance from regulation. This is due to the variety of opinions on how it should be solved. In order for this kind of data hub to work it requires that it is mandatory for all involved stakeholders to use the hub. This requires regulatory measures. [91]

SCM opens possibilities for DSOs horizontally. For instance, it would be possible to offer the customers only one phone number in case of black-outs in the larger areas, covering the whole of Finland for instance.

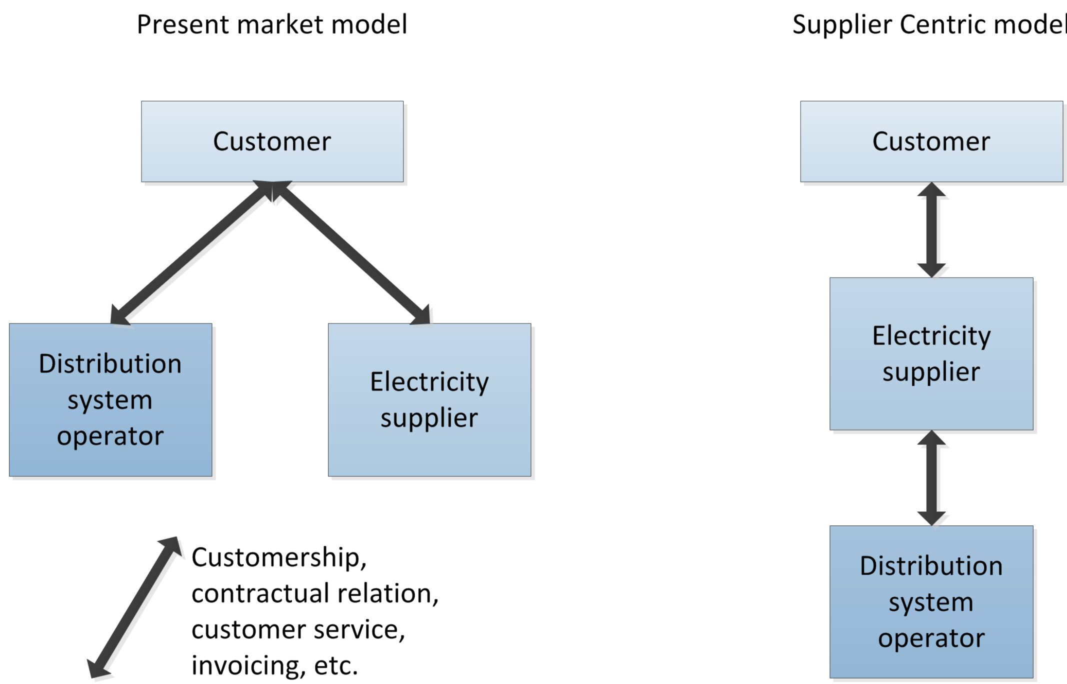

Figure 23: Present Market Model and Supplier Centric Model. Adjusted from [59].

6.4.4 DSO has possibility for market power in bottleneck situations

Synchronous load controls might cause bottlenecks to the grid. In order to avoid overload, the rules concerning priority of which loads are turned on or off has to be dealt with.

Discussion This conflict is relevant if the load control signals go through DSO for verification before taking action. DSOs role in verification is to ensure that the control does not cause danger to the grid stability. With this assumption, a scenario can be that certain area experiences power overflow if all the desired load control signals would be executed. Situation puts DSO to the difficult position, whether to decline some of the signals or no control is made during that time period. This distorts markets and is not optimal solution.

Possible Solutions Rules regarding prioritisation has to be formed in order to make the roles more clear. Bottlenecks should not produce discrimination, nor even a possibility to use market power for someone's own benefit. The regulation is needed proactively.

6.4.5 More efficient data exchange causes costs for DSO

Data collecting and distributing it forward is DSOs task. Data processing will face more strict time limits in the future. This increases incurred costs for the DSO, whereas retailer benefits from this trend.

Discussion The pressure for the pace of data exchange is increasing, and even more so in the future. It is thought that it will be as frequent as in every 15 minutes. Data verification and distributing it forward puts a strain to the DSO. It has to be done as cost-efficiently as possible. [85]

For retailer, it has positive effects. Data is available more instantly and can be used to its own processes in billing and distributing it to BRP.

Proposed Solutions If the pressure for faster data exchange comes from regulation, the compensation has to be enough to avoid unreasonably high costs which DSO faces. Cost investments for implementing efficient data exchange system can be hard to prefigure.

6.4.6 Ownership of the electricity storages are not clearly defined

Electricity storages can be used in benefit of DSO as well as retailer. In order to avoid conflicts, the rules for the new concepts has to be defined clearly.

Discussion Electricity storages and its ability to absorb energy at low price and feed energy during peak prices makes its characteristics similar to DR. In EURELECTRIC report two functional areas for electricity storages are identified:

- Energy Management – Decoupling the generation of electricity from its instantaneous consumption. (Arbitrage of energy)
- System Services – Services that are used to enhance the quality of service and security of supply in electricity power system. [57]

Areas confront each other. To use electricity to enhance quality of service means that storage does not participate in markets, which is distorting the competition. On the other hand, using the storage to gain revenue through price fluctuations can cause problems to the grid through unnatural power flows.

Proposed Solutions Adapting a new class of asset to the infrastructure always demands its role definition. Storage's capabilities to act as an generator or a consumer needs a set of rules. Comprehensive cost-benefit analysis for energy storages is needed to meet the interests of all market players. [57]

6.5 DSO – Aggregator

6.5.1 DSO might be reluctant to share the data

There is no law that 3rd party may access the data received from Smart Meters. The DSO might be reluctant to give this data away, or is able to postpone the data transfer.

Discussion Data sharing is not DSOs core business, but it is required to collect the data. If it has to distribute the data to more parties than obligated by law, DSO might be reluctant to do this because it requires extra work.

So far, DSO has no obligations to share the AMM data to aggregator. This might hinder the entrance of the new actors to the field as agreements about data ownership are still open to discussion.

Proposed Solutions Either access to DSOs data has to be made more simple or an aggregator has to find another way around this obstacle, e.g. by measuring the data itself.

6.5.2 Ability of an aggregator to use market power against DSO

An aggregator can manipulate the price of the DR to unnaturally high level, if it offers DR services to DSO in order to avoid the overloading situation.

Discussion This conflict has same characteristics similar to 6.4.4, where DSO might have possibility for using discrimination. Now the scenario is as follows: if there is no need from DSO to confirm the load control signal, an aggregator can raise the price of the DR to unreasonably high values. DSO has the pressure for purchasing in order to fulfil its duties regarding grid stability.

Synchronous control signals cause large changes in power flows, which is against DSOs wish. If the signal for the load control comes only from market-side, it results in ramped power flows.

Proposed Solutions If the system level signal is made possible for the DSO to perform, it would result in controlling the loads more evenly. Trade-off is that deregulated markets do not get full benefit from DR. Other solution is to make price ceiling for the flexibility services that are offered to the DSO. Thirdly, same solution as in 6.4.4 can be used. DSO can have right to limit the controls if there is danger situation.

6.5.3 Different signals for load controlling

The aggregation does not have differences concerning this conflict on this subject whether the aggregator is 3rd party or retailer. The main problem is that if the control signals come only from market-side, it might have coinciding effects on DSOs interests. This conflict is introduced in more detail in Chapter 7.

6.5.4 Aggregator may cause instabilities to the grid

DR can be implemented through several channels. One logical channel is HEMS. Another channel for controlling loads is a Smart Meter, which is owned by DSO. Doing the control through Smart Meter, DSO is part of the chain that is needed in order to execute switching of the load. If requests go through DSO, it has understanding on the state of the grid at given time. If controls are made only by an aggregator without any verifications needed, DSOs lose the control and knowledge about what is happening in their own grid.

Discussion The reasoning on why DSOs are active in engaging load control through Smart Meter is that it fulfils its task on ensuring the functionality of electricity markets. As DR will be an important part of the future's electricity markets, promoting and helping to capture the benefits of DR is seen as a task for DSO to be part of.

DSO ensures the markets' proper functioning by keeping the distribution grid in balance, avoiding bottlenecks and overloading of the grid components. From this point of view, it is easy to see DSO's interest towards DR. The synchronous control of loads ha an impact on grid's power flows. It is beneficial to sustain knowledge of the grid's state. Signals coming to DSO-level about planned controlling schemes help DSO to be prepared to potential intensive situations pro-actively. The knowledge about the state of the grid remains in DSOs hands.

HEMS systems might cause problems to the grid stability. Synchronous control signals to loads always cause peaking of the power to the grid. It is a question that who should carry the responsibility of this action, if it causes emergency situations to the grid. If the controls are out of the DSOs hands completely, nothing can be done to react in danger situation. [76]

Proposed Solutions Collaboration with actors are strongly recommended. DR has to be in very popular before the load shifting has bigger impacts so it is not the burning issue. Nevertheless, it is beneficial for every stakeholder to make clear rules early enough.

6.5.5 Regulatory Bottlenecks for DR services

Regulatory framework can restrict the interest of DSOs to acquire DR services.

Discussion Depending on country, the regulation model for the DSO varies. Regulation in Smart Grid should be designed to take into account the new possibilities on deferring the grid investments, e.g. DR and electricity storages.

Today, regulation does not support DR very efficiently. If DSO consumes peak shaving services, it reduces the need of physical assets. If regulation emphasizes stronger incentives for reducing operational costs with less focus on capital expenditures, DSO is uninterested on using DR services as an alternative solution for constraints. [7]

Connected to regulation and the nature of the role DSO has, it is hard to establish viable business model for offering DR services to DSOs. According to Schulz: "In theory, there can be a business model that you will sell DR services to DSOs. In Germany DSOs are struggling because there is a law that you have to buy the energy from small producers to the grid. In theory they are a good customer but in practice it will be a slower market to develop. This is partly because of the way DSO gets reimbursed. If they buy a new transformer they know exactly what to do, they buy this asset and they get their money back over time. If they buy software or IT service, the calculation for payback is not that easy since the approach is new. Regulation again: if there would be clear way how they would get paid for it, they would be good customers.” [78]

Proposed Solutions As mentioned, a healthy attitude towards regulation and laws steer the development to the right direction. Regulation should encourage new, innovative business approaches.

6.6 DSO – TSO

6.6.1 Data Communication Interface is needed

Emergence of DER demands interaction between DSO and TSO in order to keep the balance in the grid. Building interface is costly and views on how it is executed in practice vary among players.

Discussion Through DER, generation emerges in parts of the grid where it didn’t exist before. In addition, this generation has different nature as it has more complex production patterns compared to the traditional power plants. A clear interface for DSO and TSO is needed and the operations models regarding it has to be created. At present there is none, because need for interaction hasn’t existed. Before large power plants have stayed put. [77] Since there are several DSOs and several views on the outlook of the future, agreeing on interface common ground rules have proven to be difficult to solve.

Proposed Solutions It is crucial to get dialogue going between DSOs and TSO. Luckily, the actors have identified the importance of the subject. Rules about the responsibilities of reporting among actors has to be solved. [86]

6.7 Aggregator – Retailer

6.7.1 Losing market share to a new player

The most obvious challenge between these two players is that their customer segment can overlap. As mentioned earlier, if an aggregator decides to operate in markets, its role is exactly the same as the retailer. [50]

Discussion An aggregator can have different roles. From retailer’s point of view, an aggregator can be an actor who helps customer to optimize the energy usage by reshaping the energy consumption curve. In this case, collaboration is needed in order to know what kind of changes there will be, considering the balancing settlement. In this model an aggregator is basically an ICT service company to a retailer.

Another role of an aggregator includes the participation in power exchange. The need for collaboration disappears and an aggregator becomes retailer-aggregator. Both actors can have same customer base, which means that competition gets better in electricity markets.

Proposed Solutions Conflict creates natural development of markets closer to perfect competition. Penetration of aggregators to the energy business should be supported in order to enhance better market functioning.

6.7.2 Cost of forecasting errors

3rd party aggregator, which shifts energy consumption to different times than retailer forecasts can create a conflict situation.

Discussion Retailer's interest is to stay on the balance it has projected for energy consumption. A retailer has acquired the assumed amount of electricity it will need the following day from Elspot market. The margin between retailer's procurements and sales of energy has to be settled through imbalance power. Through an individual aggregator with no connection to retailer, aggregator's actions will increase the errors in next day's forecasting. The volatility of imbalance power prices cause extra risks and costs for the retailer. [36]

Proposed Solutions Collaboration with a retailer would be expected from aggregator, if an aggregator is not responsible for maintaining its balance.

6.8 Aggregator – Generator

6.8.1 Demand Flexibility brings down the market price

Demand Flexibility that an aggregator introduces presses down the market price and reduces the amount of peak prices. For generators that have a lot of flexible production, less peak prices is not desirable. It causes the diminishing of revenue.

Discussion Peak prices come up when peak power capacity is ignited in order to meet the high demand. Peak generation units have high variable costs because it usually uses expensive fuel such as gas, causing the price to go up. In the past demand has had little flexibility, so production has followed demand. If demand has flexibility, some of the energy consumption can be shifted to another time and the peak does not occur. Investing to peak power plants becomes less profitable if they are needed less. Also ones that are already built will experience the loss of revenue because peak generation units are not used as much as before.

From simple demand-supply curve in Figure 24, it is easy to show on how the DR affects the Spot-price. Investments to peak load power plants become less attractive. If there is a possibility to change demand from certain, expensive moment to another

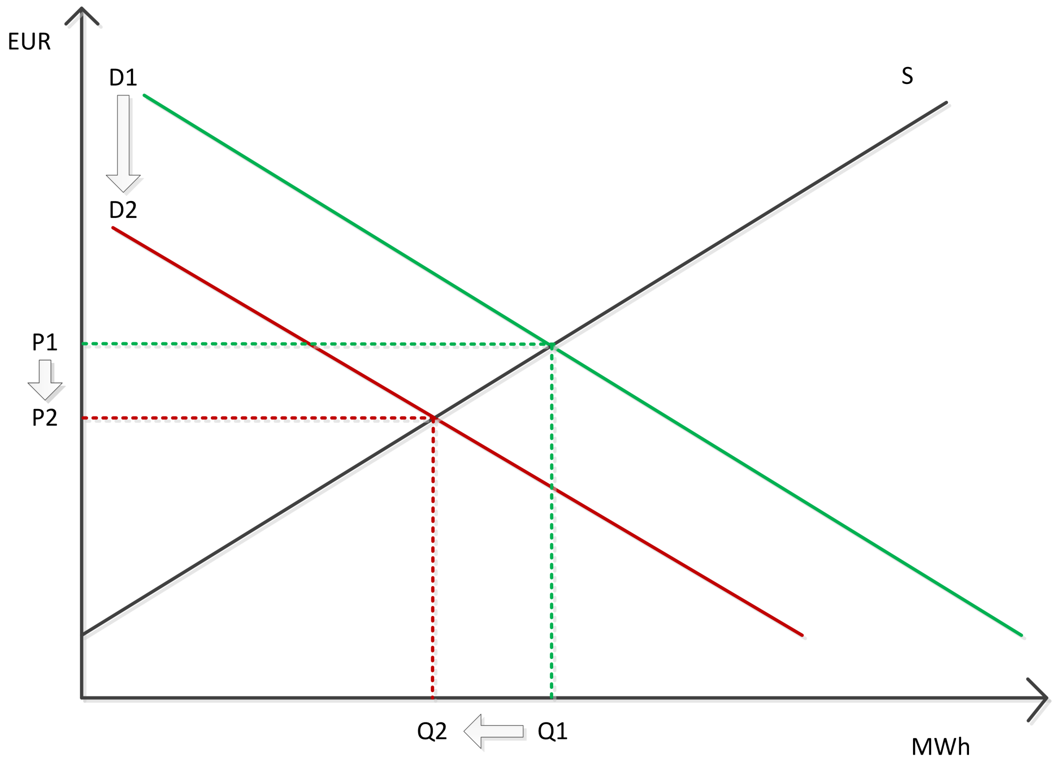

Figure 24: Demand flexibility causes the price to drop.

time, the demand curve moves to the left when the price is high. This causes the price to drop down.

Proposed Solutions Issue is the relevance of this scenario: it will be a long time before demand flexibility reaches such a large scale that it has effects on the market price. On the other hand, the power plants are long-term investments, ranging from 10-20 years. DR adds another parameter for forecasting the payback time of these projects in rapidly changing market environment.

6.9 Aggregator – TSO

6.9.1 Regulatory framework for reserves are strict

TSO's requirements for different reserves can be very specific regarding the volume and the activation time. This can create a barrier for an aggregator to fulfil the requirements.

Discussion The current regulatory frame might impose too strict requirements on the volume or the availability of reserve power. Current product portfolio has planned to fit for the traditional, large consumers or producers. First solutions for aggregation services are emerging and supporting this kind of trend would be beneficial for the markets, and for TSO. TSO is in key position to help this kind of new solutions to take on hold. From TSO's perspective, an aggregator has a very useful asset but igniting the new business is difficult At the moment it can be problematic for a small player like an aggregator to enter the market: critical mass needed is too large.

Proposed Solutions If there is a will to engage demand flexibility from small scale customers as well, changes in reserve requirements can be made to enable it. TSOs could re-think their product portfolio and create products that can help aggregators to enter the market. For TSO, it is beneficial to boost DR services further. DR has very positive effects on TSO's business, it helps to decrease costs that come from buliding reserve power and new cables. Reserve costs are expected to become multifold in the near-future, so there is definitely a need for a demand flexibility. [86]

6.9.2 Balancing destabilisation can cause volatility to TSO's balance sheet

If aggregator's actions create volatility in BRP's balance sheet, it can reflect to TSO as well.

Discussion TSO is responsible to keep the balance in its system area. This liability is delegated to BRP's who are responsible for the balance in the area they operate. Volatility in balance sheets from aggregator actions can reflect to BRP. If variation is large it can mix TSO's balance as well.

Proposed Solutions This conflict will need immense amount of aggregated loads in order to happen. Before reaching this state, the whole environment has changed as well. Communication through the different parties will help to communicate the signals forward. If there is efficient information exchange with aggregator, BRPs and the TSO, everyone could react to the situations caused by another party's actions.

6.10 Aggregator – BRP

6.10.1 Restricting an aggregator's entry to market

Concerns about competition in the market for aggregating demand response are raised. If there is requirement for an aggregator to be in agreement with BRP about controlling the loads under BRP area, it can lead to a situation where BRP can resist this action. It is against competition standards.

Discussion BRP can have interests to obtain the boundary for an aggregator for restricting its market participation. This conflict depends on countries' regulations, but an example comes from France where the competition authority identified 3 reasons for BRPs to be against aggregator actions:

1. BRP might want to eliminate a potential competitor in the balancing mechanism, since a lot of BRP are electricity generators.
2. BRP is under developing its own demand response services. The French competition authority noted that several suppliers had their own service development programmes.
3. BRP might want to resist an aggregator entry if an aggregator action reduces its own customers' consumption. Consumption reduction reflects to BRP's revenue stream negatively. [20]

Proposed Solutions Regulators have to take proactive role to ensure a stable competition situation to avoid the conflicts and make clear rules on how the aggregation should be viewed in the markets.

6.11 Generator – Customer

6.11.1 Controllability of base-load power plants and DER is limited

Base-load power plants, such as nuclear power plants are designed to produce steady generation output. If renewable power generators do not have incentive to restrict the production at times when there's excess amount of generation, the base-load power generator has to adjust the production, with power plants that are not designed for it.

Discussion The conflict occurs when the amount of DER has an impact on the overall markets. On a sunny and windy day the production rate from RES may rise to such levels that there is a threat of excess production. If the RES generators don't have incentive to restrict the production, base-load power plants have to restrict the production instead. The fact which makes the situation even more dangerous is that the RES generation might escalate quickly, in a matter of hours. The base-load power plants may not be able to respond fast enough.

Proposed Solutions If RES does not have feed-in tariffs, by introducing negative prices to the markets have the effect of restraining the excess production situations by making it unprofitable to produce more energy. Renewable production can be made flexible as well by introducing more intelligent controls where PV and wind mills can be dropped off from the grid in a controllable way if there is a surplus of production at some point of time. Also DR balances out some of the threats that are introduced by uncontrollable production.

6.11.2 Micro-generation diminishes the overall volume in markets

If customers start to evolve into prosumers, i.e. have own production, generators experience diminishing overall volume in market.

Discussion With promotion of micro-generation, energy generation will increase in customers own premises. The overall volume that is acquired from the wholesale markets diminishes, implicating utility companies suffer revenue losses. Also with energy efficiency schemes that are promoted, the overall energy need can decrease which in turn also effects to the energy consumption negatively. Third factor which affects to the energy consumption in the long run is the trend concerning energy-intensive industry. Industry has started to move away from Nordic countries to countries with cheaper cost-levels.

Proposed Solutions Governmental subsidies play a large role in the penetration speed of the micro-generation. This factor causes uncertainty for large utility companies, causing higher risk for the planning of new power plants. If the incentive strategy would be long-term and without large changes in direction, the conflict disappears. In this situation, utility companies take premeditated risk when initiating new projects.

6.11.3 Distorting the market with renewable subsidies

Wrong kind of incentives for renewable energy can distort the market's functioning and end up in non-optimal situation.

Discussion Incentives can have unintended and undesirable results consequences which do not lead to the action incentive-makers wanted in the first place. Therefore policy-makers have to be very careful in designing them. For instance, strong tariffs can create a wrong kind of incentive for the DER-owner to always produce energy as much as possible, regardless if it is needed or not. The signals from both system-level and market-level does not matter for the actor, since tariff guarantees a certain sum per energy which is produced.

In a situation where there are lots of renewable energy production in the system, the generators without guaranteed tariff see the collapsed price resulting from excess production the system experiences.

Proposed Solutions Renewable energy should be put into the system through market-based solutions. If the markets let the price to go to negative, it would result better functioning markets: generators would have the incentive to restrict the production when it is not needed. When every actor is exposed to the right signals and price levels, market's find the optimal equilibrium.

6.12 Collated Map of Potential Conflicts of Interests

Discussed potential conflicts and relationships between actors are illustrated in Figure 25. All the conflicts discussed above form a map where it is easier to see which players have most conflicting roles and which players need to re-evaluate their position in markets. It has to be emphasized that the conflicts mentioned are only potential. Somewhat expectedly, most of the conflicts are related to DSO, followed by the newcomers in the energy field: an aggregator and a prosumer. The role of DSO as a regulated entity creates friction when the possibilities to turn into a more active participant through Smart Grid emergence. The roles of new actors, an aggregator and a prosumer, are still unclear. Without history, insecurity rises on how are they placed in value network.

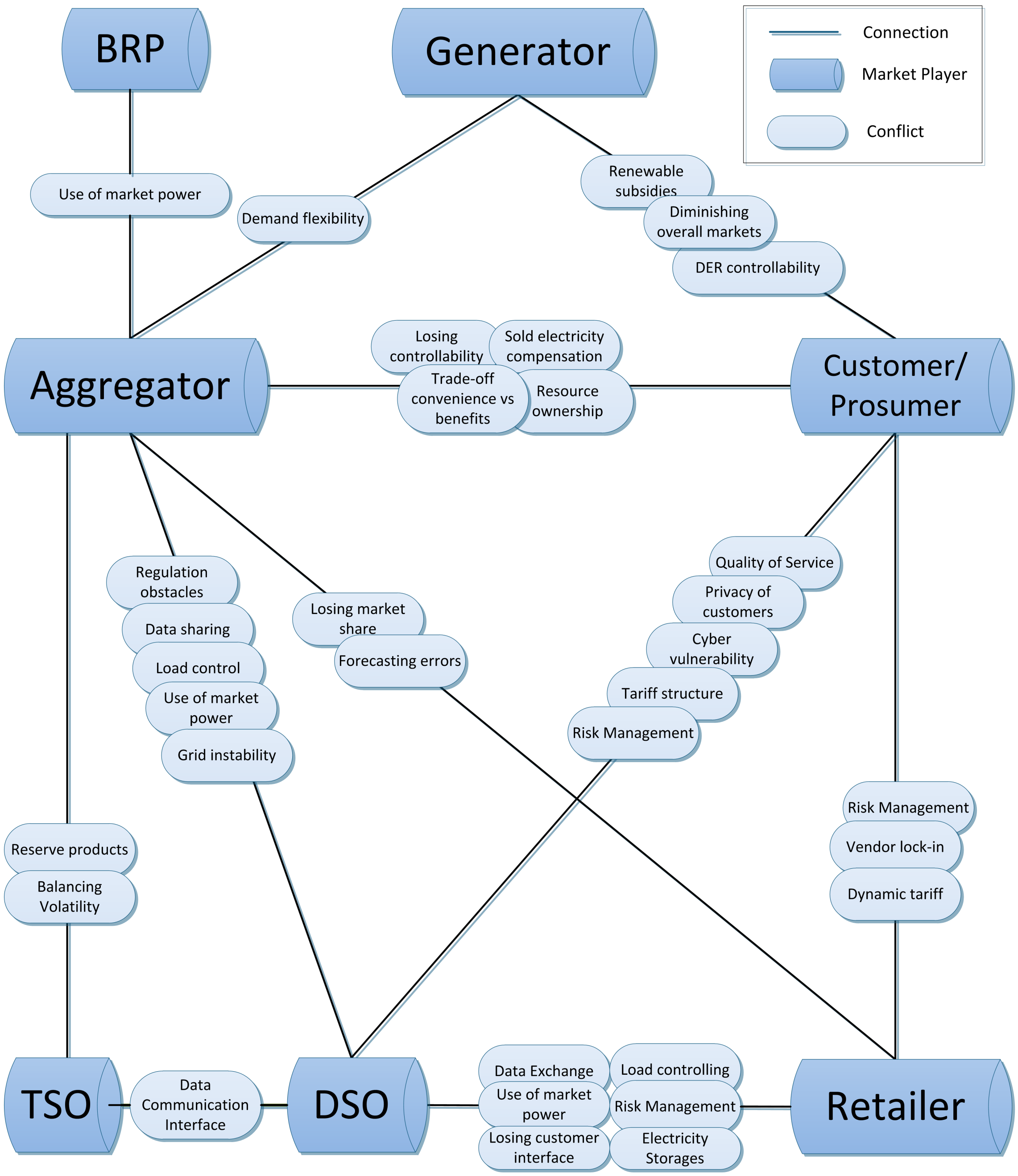

Figure 25: Map of Potential Conflicts of Interests.

7 Case study

7.1 Introduction

One of the main concerns in aggregator's emergence is the question on its effects on the grid. There can be a potential conflict of interest between the aggregator, who controls the loads solely from the signals of the electricity markets, and a DSO, who would want to keep the consumption curve as even as possible. It is suspected that aggregator's synchronous actions will raise the peak power, forcing the DSO to make additional investments on strengthening the grid against new peaks. Another negative impact can be the increased fluctuation in power flows. If fluctuation amplitude is large, the quality of service becomes harder for DSOs to maintain.

The aim for this case study is to give a clarification on what will happen to the grid if the aggregator will optimise the heating load by shifting the heating need to the cheapest Spot-hours available. In literature there has been two different views on how this will affect the grid:

1. This aggregator behaviour of controlling the loads will result more smooth load curves. It is a win-win-situation for both of the retailer as well as for the DSO. Retailer gets lower exposure to high prices and DSO will get lower congestions, lower losses and lower grid investments. [14]
2. Aggregator might create higher power peaks to the grid, since high demand isn't necessarily aligned with price peaks. This means that there will be a conflict of interest between these players. [2], [19]

This case study considers the relationship of these two actors in a scenario where an aggregator would have all the potential customers in Fortum's Finnish distribution network and control the loads according to the cheapest hours in the Spot-markets. It is analysed how the electricity consumption profile would change as well as monetary effects the Spot-priced control would result.

7.2 Background

In literature the situation has been discussed as a potential source of conflict which should be solved pro-actively by creating rules and boundaries of who can do it, what is the mechanism and the effects of aggregation action.

In Figure 26 the interfering Spot price and feeder load are illustrated.

It is shown that the peak power and hourly spot prices interfere at 22:00, mainly because of the historical reasons on how the Nordic electricity markets have developed. Reasoning behind it is found when looking at overall system level. At 22:00 the demand isn't that high anymore: most of the public, commercial and majority of industry customers have stopped working at this point. But from historical tariff structures, the heating loads are turned on approximately at this time, which causes the interference locally in the grid. Also the consumption from private customers still exist. Together these two factors cause unnaturally high peak power. [40]

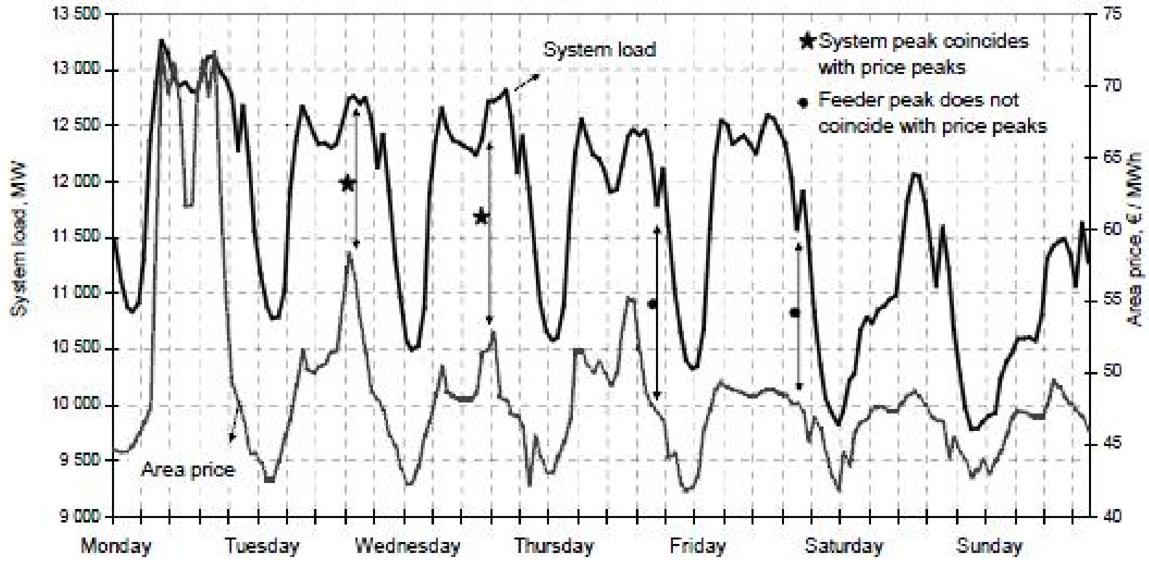

Figure 26: Hourly spot prices and powers on the time scale. [40]

In Finland, the utilization of small-scale demand response has been vastly researched. Characteristics of the country's electricity use makes it interesting: because of cold winters the electrical heating is a prevalent form of heating. Easy step to utilize it is to start by controlling the heating loads in houses. The electrical heating is rather popular in detached and semi-detached houses which are not built in district heating area.

The first step forward in this sector has been done recently. The Smart Meters can be used to do this controlling. A pilot project by Helen Sähköverkko Oy tested this approach to control the heating according to Spot prices has shown promising results. The technical aspects, the control signals for the meters have been reliable and the pilot is considered to expand further to reach 2000 customers by the end of the year 2012. [37]

Another way to do small-scale aggregation is through home automation. In September 2012, Fortum introduced a new service called Fortum Fiksu. If a house has a electric storage heating, it is possible to use Fortum Fiksu solution when control system is installed to household. The control system determines the heating need every day and chooses the cheapest hours for it automatically. It is done in collaboration with There corporation who provides the ICT-systems to make the automated control. [38] System also has connections to the future development. If the household has solar panels as well, the system takes the own production in account as well and optimizes the consumption accordingly. [38]

The case shows if there's potential challenges connected to this. It also shows the validity of services aggregator can sell to DSOs. One suggested service that aggregation will bring is the maximum peak shaving service, which can help DSOs to defer their grid investments further. The case will show whether this kind of service has enough demand to actually be economically feasible.

7.3 Assumptions

For the reasons mentioned in Chapter 7.2., the created scenario has a following composition.

- The traditional heating method requires the same amount of heating as the Spot-priced, but the heating starts at fixed time, 22:00 until the thermostat switches the load off.
- An aggregator has a direct load control over electrical heating of the customers. The customers have purchased a service where an aggregator controls the electrical heating with certain boundaries concerning indoor temperature limits.
- In the simulation the customer's behaviour is the "optimal customer" from the retailers' point of view, meaning that all the controls the retailer suggests go through.
- An aggregator operates only in Spot markets. The signal for the load control is fetched once a day from hourly Spot prices. An aggregator-retailer always chooses the cheapest hours for the heating that are needed that day, hedging does not affect on this process. This assumption is not so intuitive, but the hedging of the electricity doesn't have effect to this matter. Usually hedging is constant to a certain time-frame, which means that if there's a possibility to move physical acquiring of the electricity to the cheaper hours, it will always be profitable for the aggregator. [88]
- Customers are outside of the district heating and therefore the heating is done electrically with a heat storage, e.g. a water tank.

In Fortum's distribution area there are approximately 50 000 potential customers that could participate in small-scale aggrgation. Information should be considered with reservation since it is not known if these households have also some other sources of heating such as fire-places or geothermal heat pumps that affect the heating need radically.

7.3.1 Data needed

In order to map the behaviour of system with dynamic tariff control, historical Spot prices from Nordics are needed. In this case study dataset consists of hourly Spot area prices in Finland from January 2010 until July 2012. Prices are available in Nord Pool Spot's webpage [31].

Determining the number of hours for heating needed per day, the outdoor temperatures are required. City of Turku kindly provided this dataset for the use of this case. Data was given with hourly temperatures of the timespan January 2010 until July 2012. From hourly values the daily average was obtained. The data was collected from Oriketo.

The correlation with outside temperature and the heating need is needed to get some approximation of the system's behaviour. In this case the Formula for the amount of hours per day is used:

$$f(T) = 3 + \frac{2 \times (13 - T)}{13}, T < 13°C \quad (1)$$

$$f(T) = 3, T \geq 13°C \quad (2)$$

This Formula comes from empirical research and has been used in Helen Sähköverkko. [75]

With these datasets, the heating amount per day and the cheapest hours per day could be identified in daily basis in the timespan of two and a half years.

After identifying the cheapest hours, it was estimated that heating need stays the same compared to old situation and the graph was scaled to have equivalence with the situation experienced today.

7.3.2 Analysis restrictions

Certain assumptions had to be made, and in this section the restrictions regarding the model are discussed.

Sadly there were no AMR data available from the suitable targets, so still the analysis were done by using the estimation consumption curves. These are not completely accurate for several reasons. First of all, they are approximations to start with, and another, the estimated consumption curves are done many years ago. How people use electricity has changed over time. Still, they give good enough estimation about the nature of reality.

The calculations were done with simple model, where heating were done by switching the heating resistors on and off. In reality the resistors can be controlled with more intelligence, by turning the heat on in parts and with different power.

Another estimation where aggregator-retailer only operates in day-ahead spot markets restricts the results. In reality the retailer can, and will act in other markets as well, like in intra-day. Alas, in past it has been noted that Elbas markets have been remarkably less volatile than Elspot-markets. This might suggest that the main area of business for aggregator-retailer still is in Spot-markets. More detailed research on the business cases in Elbas-markets can be read from Valtonen et al [35].

The Formula is always an attempt to depict reality. Even though the Formula (1) is empirically tested to have a relatively good approximation, it obviously has its restrictions and is exposed to error since heating need is a complex concept with a lot of variables.

In the case, a direct control over heating is used, the customers do not have a right to override the signals. By removing the customer's behaviour reduces parameters, but in reality it is possible to tamper the temperature to a certain level. This simplifying procedure is acceptable, since the heating need is scaled to be constant at both cases: if they have got along well before nothing has changed. But, in reality an aggregator-retailer should take this into account that people might not be too keen to give all the control over to another party.

Rounding of the heating need hours to integers was done, in order to determine the amount of cheapest hours per day. This results to small variation of the indoor temperatures. It was needed partly because of the reason mentioned above, the aggregator puts on the heating for an hour or not.

The temperature dataset was lacking the dates 2.5.2010-6.5.2010.

The case study gives a hint to the direction that the situation turns to win-win situation for the DSO and aggregator. It could be useful to examine the effects on the grid in more detail when there will be real, more detailed AMR-data available.

Nevertheless, the estimations and approximations done are valid and do not affect the precision of the result too much.

7.3.3 Validity of using Spot-prices

A retailer-aggregator can offer different kinds of services to the customer. Two possible pricing structures are introduced and explained why a retailer controls the loads according to cheapest Spot-prices, having no matter which contract model customer has.

Spot-priced tariff Retailer has access for the heating load and controls it by choosing the cheapest hours from Spot-markets, bringing savings to customer's electricity invoice. Spot-priced tariff transfers the wholesale markets' price volatility risk from retailer to customer. Risk transfer implies that from retailer's perspective, it doesn't matter at what time the customer uses electricity.

Transferring the risk to customer means that electricity is not usually hedged in this situation. Price offered to customer is a Spot price with a fixed margin. If the retailer would hedge the acquired electricity, it would mean that margin would be unknown: the acquiring price is constant and sold electricity varies. If doing hedging, the retailer takes a calculated risk. [88]

Retailer still has to forecast the needed electricity one day ahead. This causes uncertainties to the retailer, independent from the tariff structure the customer has. With Spot-priced tariff, an additional variable is introduced to the forecasting: the effects of demand response to customer's behaviour has to be estimated. The load dynamics has to be evaluated when acquiring electricity, how much the Spot price-dependence shapes the customer's consumption profile.

In this tariff structure, the signal comes from the Spot-markets. The customer pays for the service: customer makes the contract which allows the retailer to control the loads, optimizing the electricity consumption to the cheapest possible Spot-hours. With Spot-priced tariff structure, using Spot-prices in calculations gives a realistic results about retailer's actions.

Fixed savings Another potential service imitates the contracts that are popular today. Customer has a fixed price for electricity, but a retailer offers a service where it can control the loads with certain boundaries, and a customer gets fixed savings from the electricity invoice.

In fixed energy-based tariffs the risk for price volatility is at retailer's side. It implies that the retailer has an interest towards controlling loads in order to avoid price peaks and help to optimize the electricity acquirement processes.

Retailers are exposed to price and volume risks, caused by high volatility of the electricity markets. Different financial instruments can be used to minimise the exposure to these risks. Retailers try to lock the gross margin by hedging the estimated electricity need beforehand.

Figure 27 shows an illustrative example on how hedging can be done. Figure shows the hedging of the Q1 in 2010. Electricity prices can be fixed for instance with forward products ENOQ1-10, which reflects the expected prices in the whole Q1 time period, and the products for every month: ENOMJAN-10, ENOMFEB-10 and ENOMMAR-10 respectively. Different retail companies have different methods for securing the electricity. The strategies differ in product portfolio mix (amount of each product in portfolio), when the products are bought and the hedging level (the amount of electricity secured from the total needed electricity).

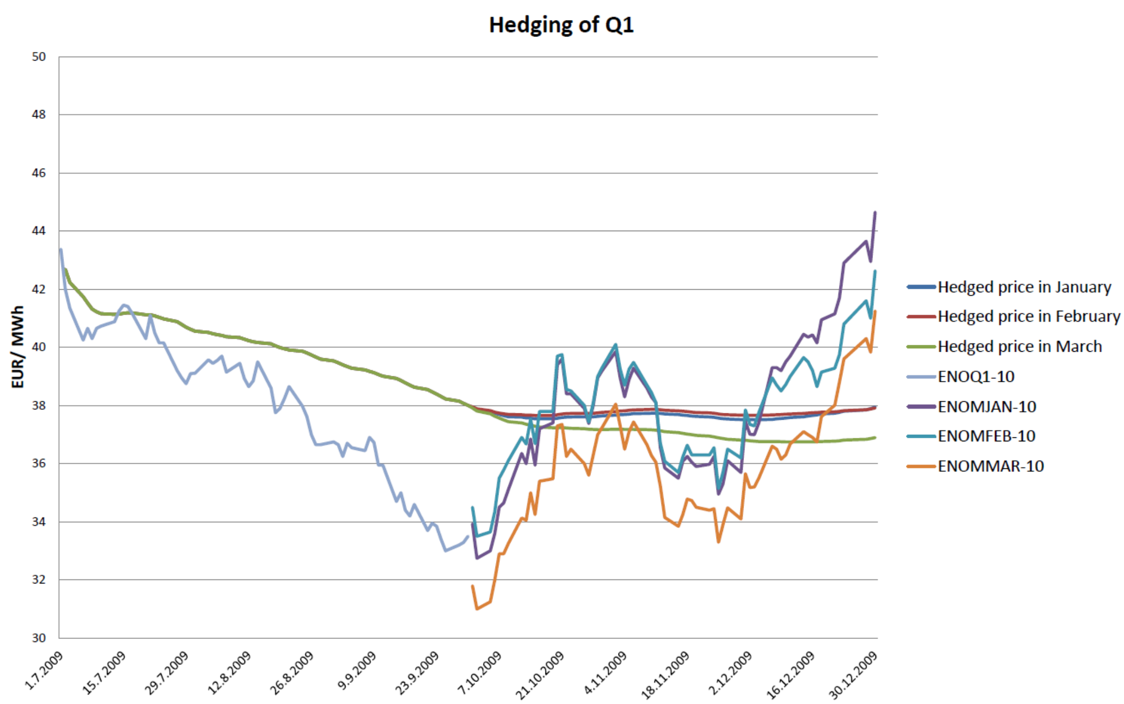

Figure 27: An example on how the hedging price is created for certain time period.

From hedging, the secured price level is constant for the whole time-frame in question. This results that if physical electricity acquiring from Spot-markets can be optimized to cheapest possible hours, it is beneficial solution for the retailer. [88] Hedging does not affect to the function on how the loads are controlled, if operating only in Spot-markets. Retailer always chooses the cheapest hours per day, regardless of the contract he has with a customer. Therefore Spot-prices are valid in simulating retailer's actions.

Obviously, this load control can be offered to other parties as well, e.g. DSO and TSO, but in this case study it is assumed that the control signals come only from Spot markets.

7.4 Analysis

This section covers the analysis and the discussion of the findings. Analysis is done for the whole time-frame between 2010 – 2012 to see the overall effects on more intelligent control. Heating is needed mostly in wintertime and therefore section 7.4.3 concentrates on the effects that are experienced during winter, from the beginning of November until the end of the March.

Figure 28 clarifies the process on how the graphs are created. This process is repeated for every day between 2010 – 2012. Cumulative results give us insight on how the heating would have been controlled in the past.

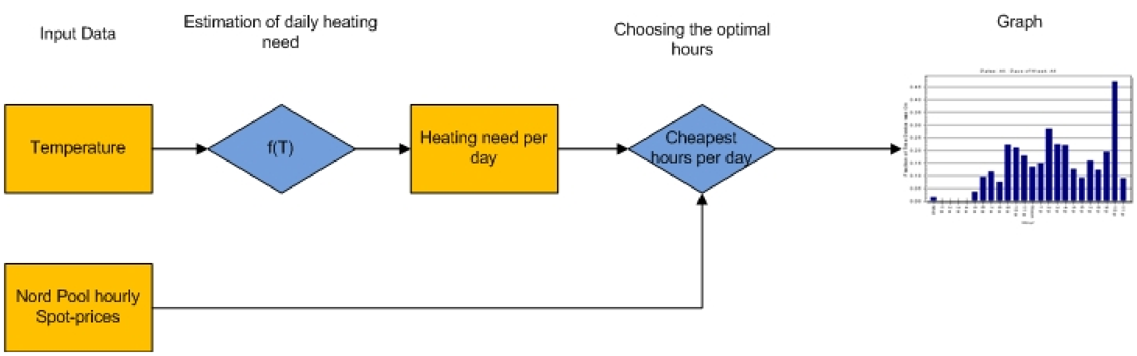

Figure 28: Aggregator behaviour simulation for one day.

Calculations and data sets are shown in more detail in Appendix B.

7.4.1 Comparison on heating control methods

Spot-priced control of the loads have an impact on the traditional heating patterns. In Figure 29, the simultaneous control signals in both methods are depicted, i.e. when both control methods give the signal for turning the heating on at the same time. As it can be easily seen, the signals do not coincide a lot, only 34 % of the time during the year of 2011. Largest differences can be seen during the summer months, as the heating need reduces significantly. Traditional control does not coincide with day's cheapest hours during summertime. The difference between summer and winter has a connection to the fact that the reduced heating need leaves more options to choose the cheapest hours, as in winter time the heating need is higher, diminishing the amount of chosen hours to be significantly less.

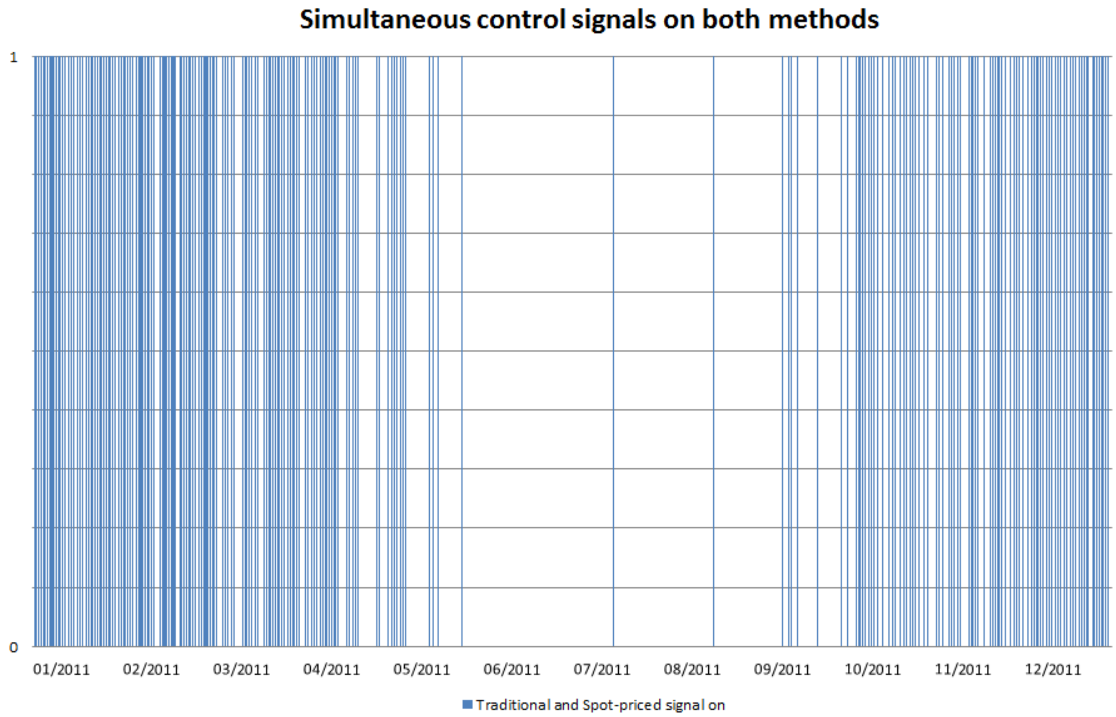

Figure 29: Signals from different control methods coincide only 34 % of the time in 2011.

Although the largest changes in heating allocation patterns is in summer-time, it mainly has monetary benefits. For potential conflict situation with DSO, the wintertime period is examined. The grid constraints are likely to happen in winter as there is higher overall demand which puts stress to the grid. In next two sections the heating allocation is examined, focusing on winter-time.

7.4.2 Heating allocation in years 2010 – 2012

Based on the calculations, an allocation in different hours of the day could be created. Figure 30 presents the allocation of heating hours for every year, showing the heating time of day, i.e. cheapest Spot hours. From the graph we can see that shape of the curves are similar every year, with heating being used mainly very late at night. The heating need varies year by year. Largest difference is seen in 2012, which has been exceptionally warm causing diminishing heating hours. Interesting feature which Spot-based control introduces is the small cluster of cheap hours during daytime: between 12:00 – 16:00 a few hours would have been optimal to use for heating.

As it is shown, the heating hours are mainly in night time, starting from 23:00, peaking at 3:00 until fading approximately at 06:00. In normal households the consumption from other activities is rather small. Energy consumption for heating does not coincide with other consumption which implies that power peaks do not increase because of this action. Power peaks stay at the same level as before, but

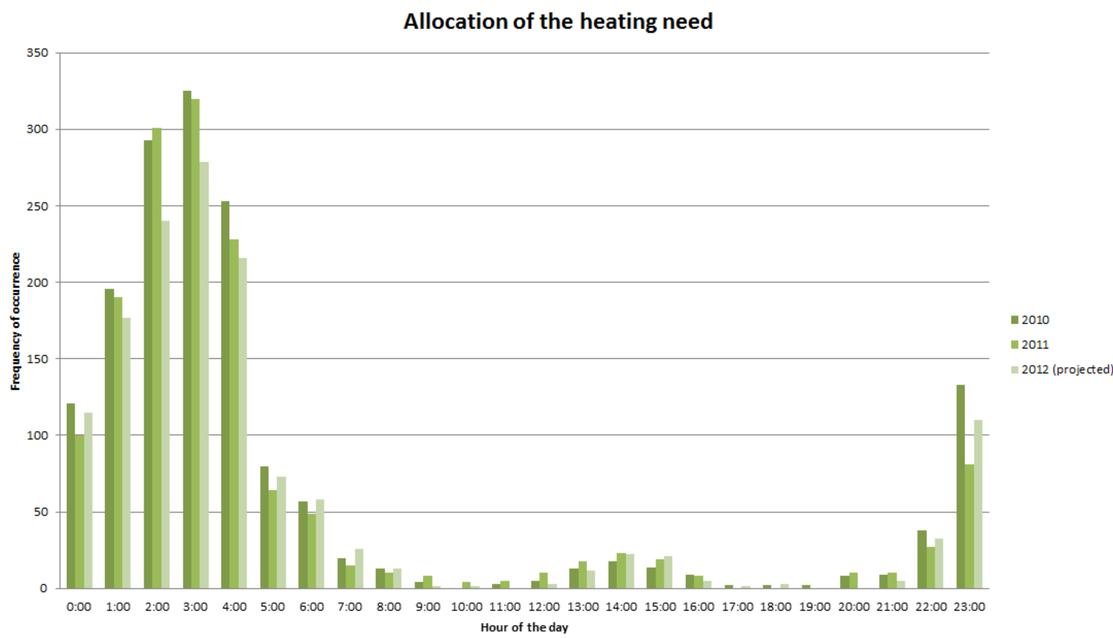

Figure 30: An average allocation of hours 2010-2012 (2012 extrapolated).

the 22:00 peak becomes rather exceptional than mundane. Price at 22:00 has not been very cheap historically, meaning that heating would not be ignited very often at this time.

If the DSO would have an option to buy peak shaving services from these hours, it could defer the investments that come from strengthening the grid. In order to buy this kind of service, DSO should have an incentive to do so. More importantly, retailer has to make sure that DSO can rely to get the peak shaving when he needs it. Otherwise it becomes too risky for DSO to even consider this option.

7.4.3 Heating allocation in wintertime

It is important to examine the most potential conditions for conflicts. This is in wintertime when the heating need and therefore the consumption of electricity is highest and the overloading risks of the distribution grid can be a potential threat. Winter is examined in more detail next. The wintertime in Finland is defined in literature to be between 1st of November until 31st of March. [43] The analysis of the discrepancies is shown in Figure 31.

In graph 31 the difference is seen between the situation today and with aggregation with Spot-markets. Graph of optimised Spot-priced heating is an average from winters 2010-2011. The reference graph is a traditional consumption graph which is taken from a research of typical load diagrams, conducted in Finland and used generally. [43] The exact hour values of it has been redrawn from the drawing of the printed publication by the author.

From graph it can be seen that Spot-priced control changes the consumption

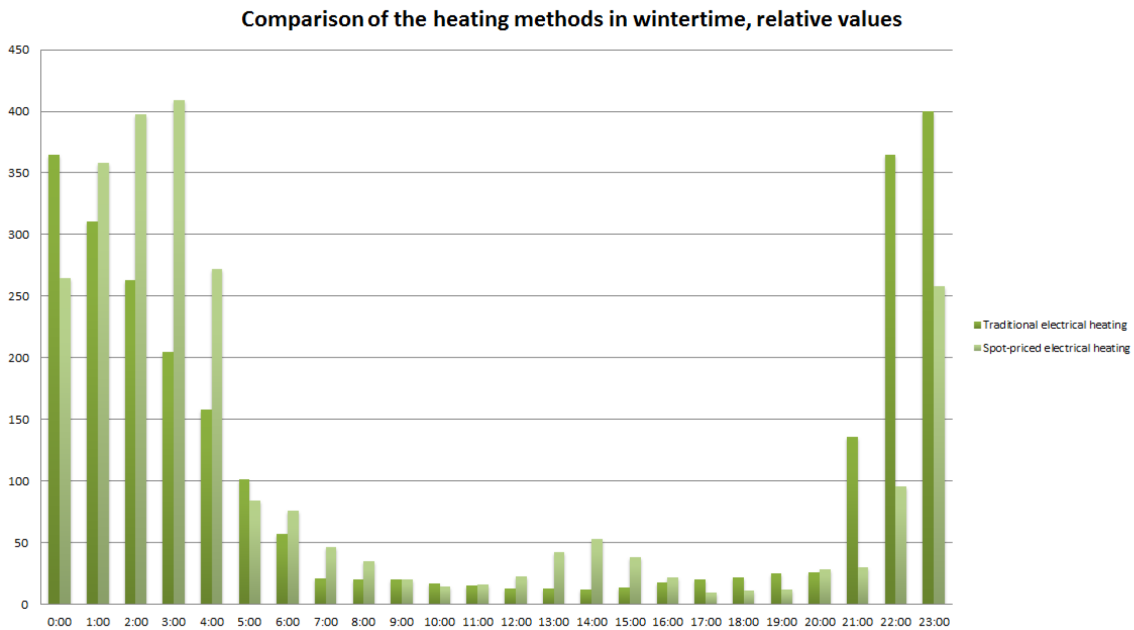

Figure 31: Change in detached house consumption curve (graphs standardized).

curve radically. The heating hours shift to a later in the night. The traditional curve start heating already from 21:00, peaking at 23:00 and fading at 06:00. Spot-priced control has a tendency to begin heating at 23:00, peaking as late as 03:00 and fading at 05:00.

The peak power is likely to shift later in the evening. As it was mentioned in the introduction of the case study, the 22:00 evening peak is seen as a problem for the DSO point of view, what we can notice from the traditional consumption curve. This peak hour shift actually serves also the interest of the DSO since now it doesn't coincide with other consumption in households.

7.4.4 Monetary value of the service

As mentioned in Section 7.4.1, the largest differences in control signals appear to be in summer-time. Even though the heating need is decreased to minimum amount, the potential savings with Spot-priced control comes from this time period.

In Figure 32, the cumulative savings for the year period are illustrated. In examined time period, the largest savings come from the summer-time period, approximately from May until the end of August.

During winter, the heating need is larger which results to more hours overlapping. The momentary savings can be higher if the evening hours that traditional heating method uses are exceptionally expensive. Ripple downwards in cumulative costs results from the model's simplicity, as it updates the Spot-prices once a day. If the device would have continuous monitoring of the prices and temperature, it would update the cheapest hours every time the Spot prices are released, at 12:00 CET,

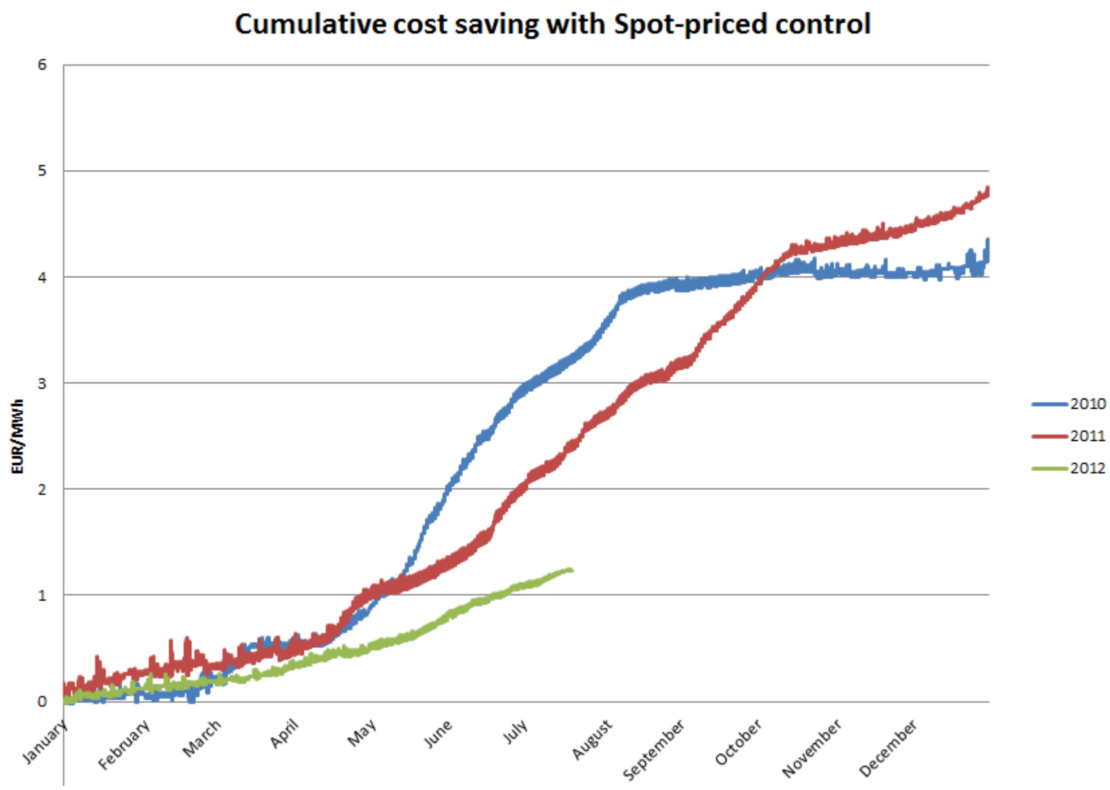

Figure 32: Cumulative savings from Spot-priced control.

optimizing the heating up to 36 hours ahead. In a case study, the time resolution is fixed for the next 24 hours.

It is shown that changes in more sophisticated heating control create savings for customers. With intelligent service design this potential can be exploited and benefits can be divided to other actors as well.

Estimations used for the calculation include the whole potential customer base in Fortum's network in Finland, which is approximately 50 000 customers. With 8 kW heating resistors, the monetary difference between traditional heating usage and control by cheapest Spot-hours per day were examined. The results are presented in Table 7.

For an average household, the drop in average Spot price can be as high as 4,76 EUR/MWh. For a individual customer with 8 kW heater, the decrease in electricity invoice would result in approximately 57 euros per year. It is difficult to convince the customer from the benefits of this product, since the total electricity consumption in detached houses are high. With estimation of 13 MWh, the yearly electricity invoice would be close to 2000 euros. Saving of 57 euros might seem meaningless for some customers.

Nevertheless, in a large scale, putting together the small savings, the potential sum for the whole network area cumulates to several millions of euros. Small adjustment to controlling would create a lot smarter system that takes into account

Table 7: Yearly differences in average spot prices and amount of potential saving.

Year	Spot average old	Spot average new	Difference	Heating need	Potential revenue
	EUR/MWh	EUR/MWh	EUR/MWh	hours/year	EUR
2010	52,23	48,10	4,12	1611	2 658 000
2011	48,06	43,30	4,76	1497	2 853 000
2012 (extrapolated)	30,16	27,92	2,25	1600	1 440 000

the overall optimization of electricity markets.

7.5 Results

7.5.1 Spot-priced control transfers the heating to later at night

From a case study, two major findings can be presented:

1. With Spot-priced control of the heating loads, the peak hour appears later in the night, at 03:00.

2. With Spot-priced control of the heating loads, the majority of the heating hours are shifted even later in the evening compared to the traditional control method. This results in less interference to the other consumption, thus lowering the peak load in customers' premises.

The case study suggests that compared to the situation today, the risk of conflict between aggregator and DSO diminishes. There is a possibility that the cheap price in Spot prices causes the evening consumption power peak as mentioned in [40], but closer exploration of the historical prices show us that most of the time electricity isn't cheap enough at 22:00 for an aggregator to put the loads on. The loads tend to be turned on at 23:00, continuing to rise and peak at 03:00. The interference with other consumption is reduced drastically. From this result it can be stated that even though signals come only from the market-side, it is a win-win-situation for both DSO and an aggregator.

7.5.2 Monetary effects

From the case study analysis, we get the result that in Fortum's network area the potential savings of Spot-priced control of the heating loads is significant. The amount of potential customers in grid area will result vast savings, up to 2 850 000 euros per year. As the Smart Meters can be easily programmed to control the loads optimally, the aggregation brings savings for the customer as well as for facilitator. The challenging aspect with this is in the same category as in penetration of larger scale DR schemes as well: there is not enough incentives for a customer to accept this kind of arrangement if the saving potential is rather small, varying from 30 – 57 euros per year.

Another aspect that has to be considered before this kind of control can take on hold is the retailers interest for creating this kind of service. In order for customers to benefit fully from this, the Spot-priced tariff is a requirement. The retailer moves the risk of fluctuating electricity prices to the customer. Usually these tariffs have the certain margin to cover the forecasting errors from actual consumption and other incurring expenses, but the risk of using or not using the electricity during expensive hours is transferred to the customer.

As long as the fee for the customers is energy-based and attached to a Spot price, from retailer's perspective it doesn't make a difference on what hour the customer uses the electricity. Retailer acquires the electricity from Spot-markets and hedging is not needed. The main reason for the retailer to get interested in this functionality is the competitive advantage over others for creating a product which helps the customer to save money and therefore making it look more attractive. Third option is to generate a product which would engage a part of the savings to the benefit of the retailer. This solution would acquire some agreements with a customer for the dividend of the sum.

8 Conclusions

In the fast evolving market environment, the actors have to adapt to the new conditions. Changing conditions force the actors to re-design their position and role in the value network. As the new positions are formed, stakeholders experience friction with each other since many actors has similar interests.

This thesis mapped the most potential conflict situations among players that can escalate in presence of a Smart Grid. Furthermore, main challenges and possibilities that a Smart Grid introduces were presented. Third part focused on the relationship between an aggregator and the DSO. It has been debated that actions of an aggregator might result in conflict situation with DSO. A case study was made to investigate the matter. It was discovered that in Nordic electricity markets domain, the Spot-priced control of the loads shifts the heating need to the night-time, overlapping less with other consumption in households.

8.1 Changes in roles and potential conflicts between stakeholders

The review from the challenges and possibilities concludes, that problems are mainly set in the interface of the regulated business and non-regulated business. A Smart Grid enables new concepts, such as Demand Flexibility and Distributed Energy Storages, which have qualities that can ease the trouble that is experienced in the system side. Problematic is that the same qualities, Demand Response and Energy Storages, can be introduced on the open competition side as well. Electricity environment will need clarification on what is the role of a regulated actor DSO in the future.

Issues regarding the regulation was raised. The consistency for the regulatory policies has not been satisfactory. The long-term strategy has not been consistent and new rules are often adapted at fast pace. Too rapid changes to the strategy moves the players' actions further away from the optimal equilibrium, since the predictions about the future become more difficult to see. A trust to long-term regulation is lacking at the moment, which hinders the development and reduces the interest for long-term investments, if the return of investment cannot be determined to an accurate level.

A lot of expectations are built up for the EU-level regulation. Doubts whether the situation will take turn for better are sceptical since every member country has its own policies: a consensus for the best model hasn't been reached, hindering the creation of an integrated EU electricity markets.

In total, 33 different conflicts were discovered, and two themes were highlighted above others in determining the most critical questions. First, the changes in energy production structure and second, the integration of ICT to the energy industry.

The emergence of a small scale renewable energy production have a large impact on the power generation structure, making it less flexible. Growing inflexibility in energy production side causes the pressure for the demand side to be elastic, implicating that in future the DR will become more valuable.

The intermittent nature of DER weakens the accuracy of forecasting, as it is brought to the Spot-markets one day before the actual delivery. It is harder to forecast the actual production and consumption beforehand. A possibility to bring DER to the markets as flexible bids is suggested.

The renewable energy subsidy policy needs to be designed carefully, in order to achieve the wanted goals without undesired effects. Subsidies easily distort the behaviour of the markets, resulting in suboptimal solutions from the society's point of view.

Second theme evolves around the topic on transition from analogue world to digital world. Creating the comprehensive ICT-system over the organizational boundaries requires holistic approach in order to succeed. Design of a functional Information Exchange is a crucial factor to be solved, which needs collaboration from all the stakeholders in the field.

Emergence of the new players, an aggregator, prosumers and ESCO, was seen as a positive development in energy business. New players concentrate on the very main challenges the electricity sector experiences: inability for flexibility as well as for inability for storing electricity. The consensus was that bringing flexibility to the demand-side is an essential part of well functioning markets. Undefined roles of new stakeholders in electricity domain raises questions among existing players.

8.2 Conflict between an aggregator and DSO

In literature, it has been stated that aggregation might result in a conflict situation between an aggregator and DSO, because an aggregator takes advantage from the price differences in the electricity markets, shifting loads to the cheapest possible time. In micro-level from DSO perspective, situations exist when the synchronous load control can result in the increase of the peak load, thus posing a threat for more grid congestions. Grid congestions can escalate even though the overall demand, and hence the wholesale markets' system price, is low.

In thesis, the effects of an aggregator action in Finland was studied. Finland has untapped potential for the small-scale Demand Response because of the large amount of electrical heating used in house-holds. The situation, where an aggregator controls the loads according to the Spot-prices were analysed. Study presents that compared to the traditional load control method, the heating need shifts later to the night. At present, heating causes the peak at 22:00, when there is electricity consumption from other electrical devices as well. With Spot-priced control, the peak would be at 03:00. During the night, the electricity consumption from other electrical devices in households is minimal. Hence Spot-priced control method would improve the situation by decreasing the peak load.

8.3 Recommendations for further research

Thesis mapped the comprehensive picture on the conflicts of interests from different stakeholders' perspective. Information Exchange and the effect of renewable production were discovered as the key issues that have an influence to the future outlook.

Further research on different Information Exchange models and their potential should be researched in more detail. The implementation of the common data hub among players has far-reaching impacts for the whole sector, so the questions regarding the data hub and its functionalities need further research.

8.4 Recommendations for Fortum

This thesis investigated the potential changes in roles and responsibilities from the perspectives of different stakeholders. Fortum Corporation acts as an generator, a retailer and as a DSO. Therefore, three relevant recommendations for the Fortum are as follows:

1. Explore and conduct a market research for exploiting the small-scale aggregation business.
2. Be strongly committed and promote the collaboration for the creation of a central data hub.
3. Pro-actively explore the effects for the business in case of EU-wide capacity markets.

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A Appendix A

List of the interviewees:

- Päivärinta, Joonas. Development Manager, Helsingin Energia. Interview in Helsinki 27.7.2012.
- Segerstam, Jan. Development Director, Empower. Interview in Espoo 28.6.2012.
- Heine, Pirjo. Electric Grid Expert, Helen Sähköverkko Oy. Interview in Helsinki 28.8.2012
- Seppälä, Joel. Customer Relationship Manager, Helen Sähköverkko Oy. Interview in Helsinki 28.8.2012.
- Hiekkala, Juha. Development Manager, Fingrid Oyj. Interview in Helsinki 31.8.2012.
- Schulz, Thomas. CEO, Entelios AG. Interview via phone 1.8.2012.
- Hänninen, Kenneth. Director, Energiateollisuus ry. Interview in Helsinki 20.8.2012.
- Salomaa, Pekka. Director, Energiateollisuus ry. Interview in Helsinki 20.8.2012.
- Kiviluoma, Juha. Senior Scientist, VTT. Interview in Espoo 22.8.2012.
- Matilainen, Jussi. R& D Manager, Fingrid. Interview in Helsinki 4.9.2012.
- Sederlund, Jarno. Customer Manager, Fingrid. Interview in Helsinki 4.9.2012.
- Merkel, Marcus. Senior Advisor to the Managing Director. EWE NETZ GmbH. Correspondence via email 29.8.2012.
- Söderlund, Bengt. Regulation Coordination Manager, Fortum. Interview in Espoo 12.9.2012.
- Jäppinen, Jonne. Fingrid. Interview in Helsinki 12.9.2012.
- Iso-Tryykari, Mikko. Business Development Manager, Fortum. Interview in Espoo 17.9.2012.
- Vaitomaa, Janne. Development Manager, Fortum. Correspondence via email 23.7.2012.
- Nora, Markus. Analyst, Energiamarkkinavirasto. Interview in Helsinki 18.9.2012.
- Rintamäki, Mikko. Managing Director, Elfi. Interview in Helsinki 7.9.2012.
- Wickström, Anders. Development Manager, Fortum Markets. Interview in Espoo 20.9.2012.

- Häkli, Jukka-Pekka. CEO, SEAM Group. Interview in Helsinki 19.9.2012.
- Eriksson, Egil. Senior Advisor, Fortum Power and Heat Oy. Interview in Espoo 31.10.2012
- Nordblad, Karl-Henrik. Senior Advisor, Fortum Power and Heat Oy. Interview in Espoo 31.10.2012
- Lehto, Ina. Advisor, Energiateollisuus. Interview via phone 18.10.2012.
- Saarinen, Jarmo. Long-term Planning Manager, Fortum Distribution. Interview in Espoo 15.11.2012
- Tenschert, Walter. Managing Director, Energie AG Oberösterreich Netz GmbH. Correspondence via email 15.11.2012.

B Appendix B

This section presents background information for the calculations which were conducted for the case study 7.

In Figure A1, the graph for the yearly average temperatures and the daily heating need is shown, ranging from three to nine hours. These are rounded numbers with minimum limit to three hours. Also the accurate results from Formula (1) is shown, to show the comparison.

From the heating need per day with addition data set of Nord Pool Spot's hourly Spot-price, the control signals for loads is created. This procedure is illustrated in Table A2. Three days from the whole dataset is extracted, showing the differences in fraction of three days, to illustrate the possible differences in controlling methods.

Figure A3 shows the volatility of the Spot-markets, with price peaks cut from graph. The Spot-priced load control is shown on red color. It is to demonstrate the saving potential the more intelligent control method can introduce.

For monetary savings, the heated hours connected to the control method in question is presented in Figure A4. It shows the potential of monetary savings throughout the year, with main savings in summer-time.

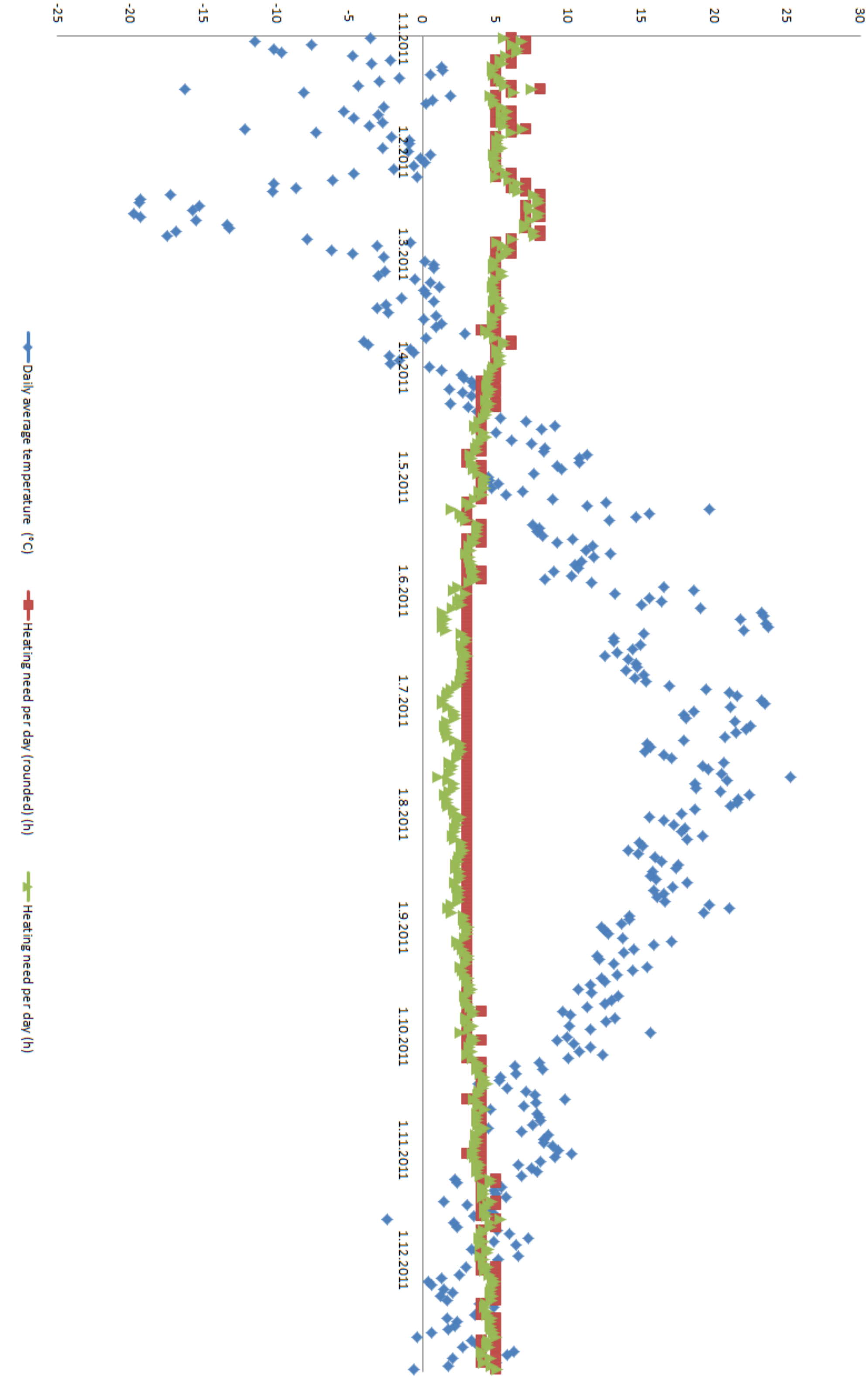

Figure A1: The daily average temperatures and the heating need per day in 2011.

3.2.2012		4.2.2012		5.2.2012		6.2.2012	
Hour	Spot price	Hour	Spot price	Hour	Spot price	Hour	Spot price
00 - 01	45,9	00 - 01	50,73	00 - 01	44,27	00 - 01	41,19
01 - 02	43,8	01 - 02	46	01 - 02	42,88	01 - 02	40,88
02 - 03	42,16	02 - 03	44,52	02 - 03	41,32	02 - 03	40,82
03 - 04	42,52	03 - 04	45,2	03 - 04	41,13	03 - 04	40,19
04 - 05	44,08	04 - 05	45,68	04 - 05	41,24	04 - 05	42,41
05 - 06	60,06	05 - 06	44,19	05 - 06	40,69	05 - 06	44,52
06 - 07	211,92	06 - 07	42,65	06 - 07	40,67	06 - 07	58
07 - 08	199,91	07 - 08	44,25	07 - 08	40,58	07 - 08	100,4
08 - 09	207,02	08 - 09	46,74	08 - 09	40,56	08 - 09	120
09 - 10	181,3	09 - 10	53	09 - 10	43,18	09 - 10	108,58
10 - 11	86,09	10 - 11	55,54	10 - 11	42,82	10 - 11	101,61
11 - 12	84,71	11 - 12	51,27	11 - 12	42,82	11 - 12	90,91
12 - 13	67,7	12 - 13	48,19	12 - 13	41,12	12 - 13	79,93
13 - 14	60,06	13 - 14	45,21	13 - 14	39,32	13 - 14	79,6
14 - 15	60,07	14 - 15	44,22	14 - 15	39,21	14 - 15	73,9
15 - 16	60,09	15 - 16	44,94	15 - 16	41,53	15 - 16	73,7
16 - 17	148,36	16 - 17	50,99	16 - 17	43,34	16 - 17	84,97
17 - 18	198,73	17 - 18	70,58	17 - 18	51,91	17 - 18	118,58
18 - 19	111,5	18 - 19	103,46	18 - 19	58,91	18 - 19	142,9
19 - 20	75,21	19 - 20	67,11	19 - 20	52,9	19 - 20	124,78
20 - 21	57,95	20 - 21	51,97	20 - 21	45,58	20 - 21	66,41
21 - 22	50,71	21 - 22	47,94	21 - 22	45,03	21 - 22	52,93
22 - 23	53	22 - 23	47,42	22 - 23	43,86	22 - 23	45,03
23 - 00	44,28	23 - 00	43,44	23 - 00	42,74	23 - 00	42,77

Traditional control

Spot-based control

Figure A2: Differences in heating control methods.

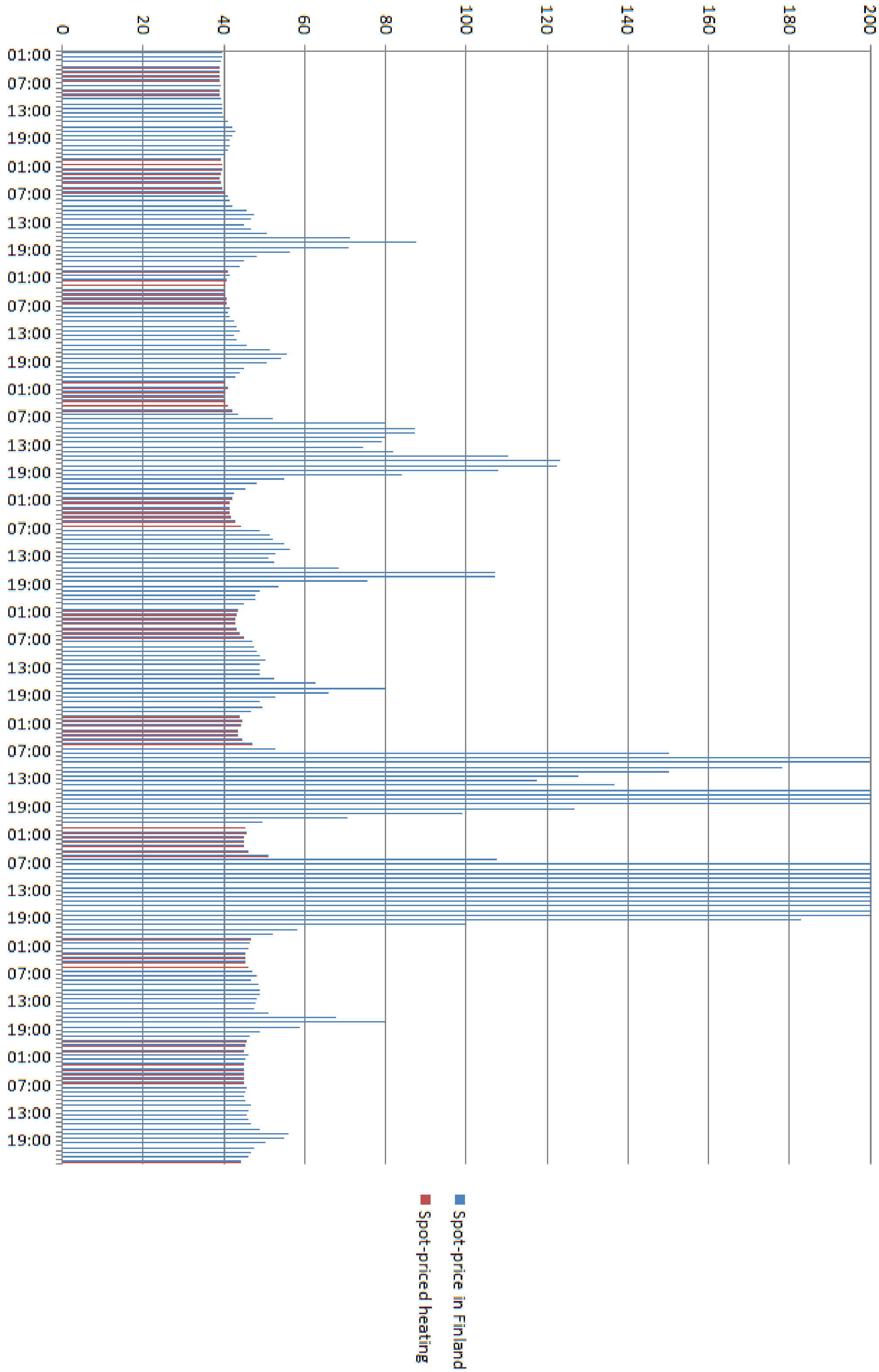

Figure A3: Heating based on Spot-prices avoids the price peaks, example extracted between 1.1.2010 – 10.1.2010.

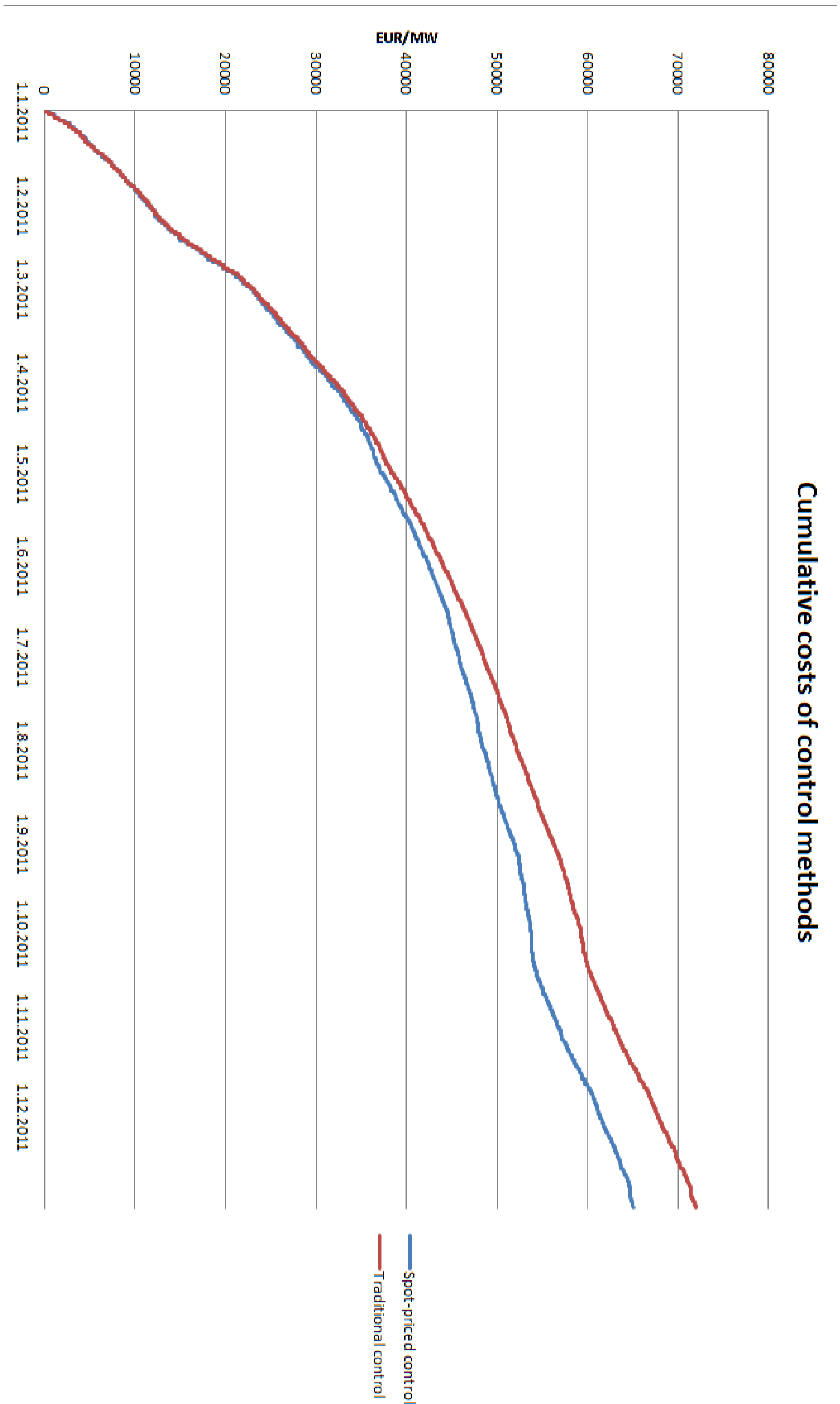

Figure A4: Cumulative costs of control methods in 2011.